THE FUELS
OF THE HOUSEHOLD

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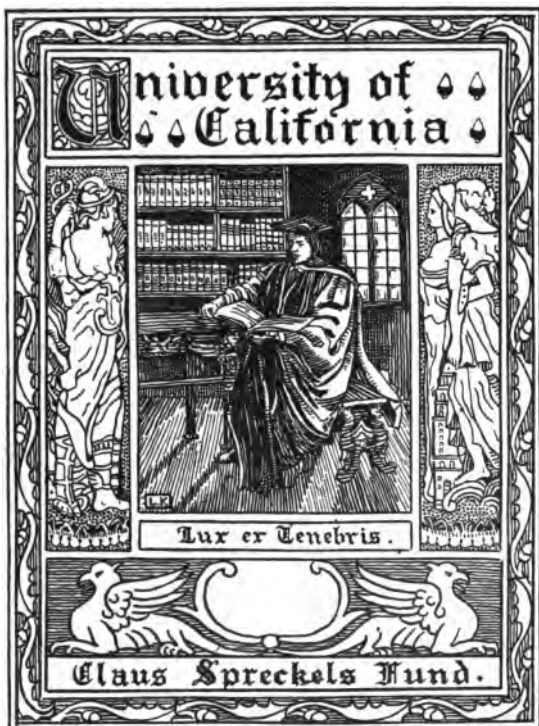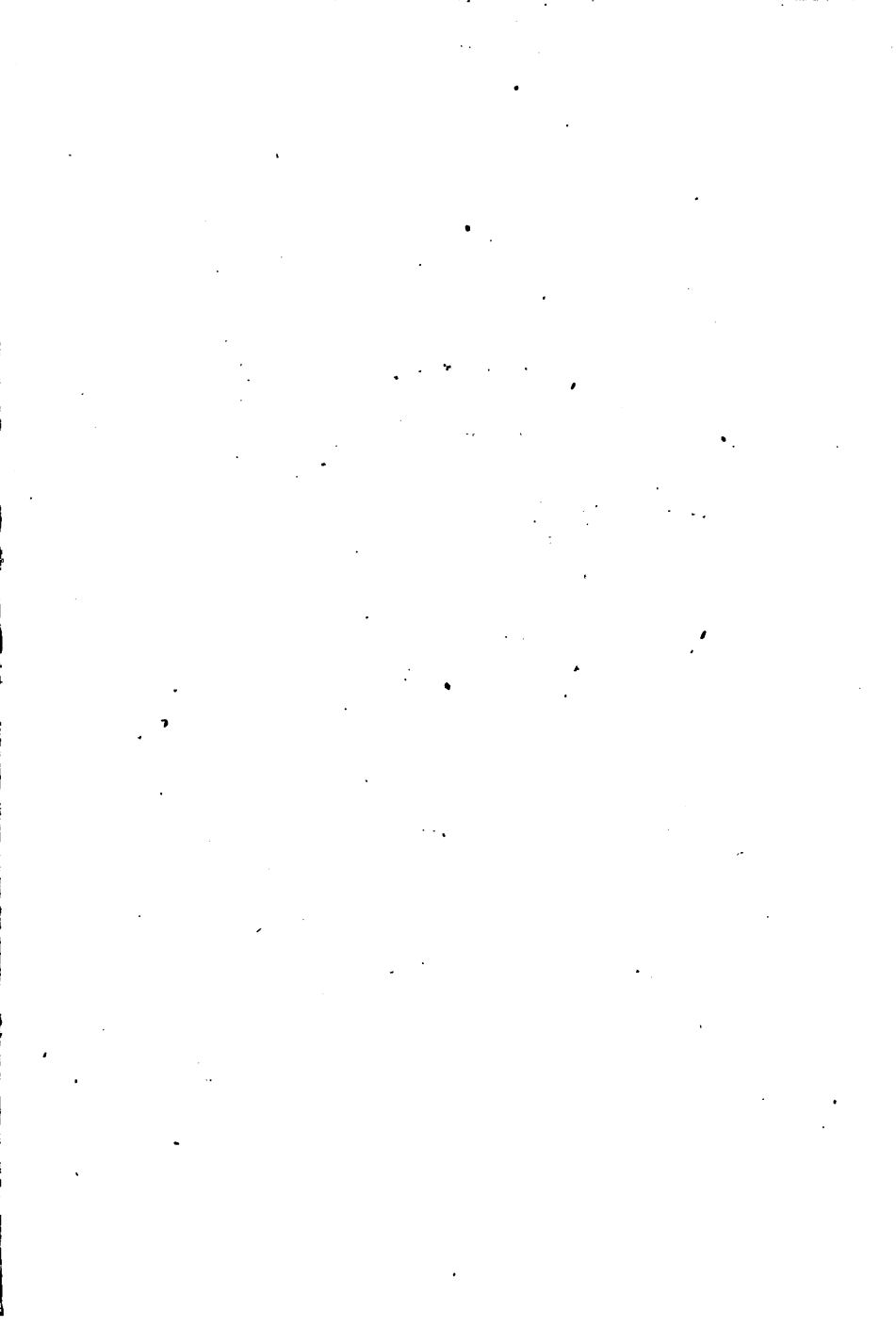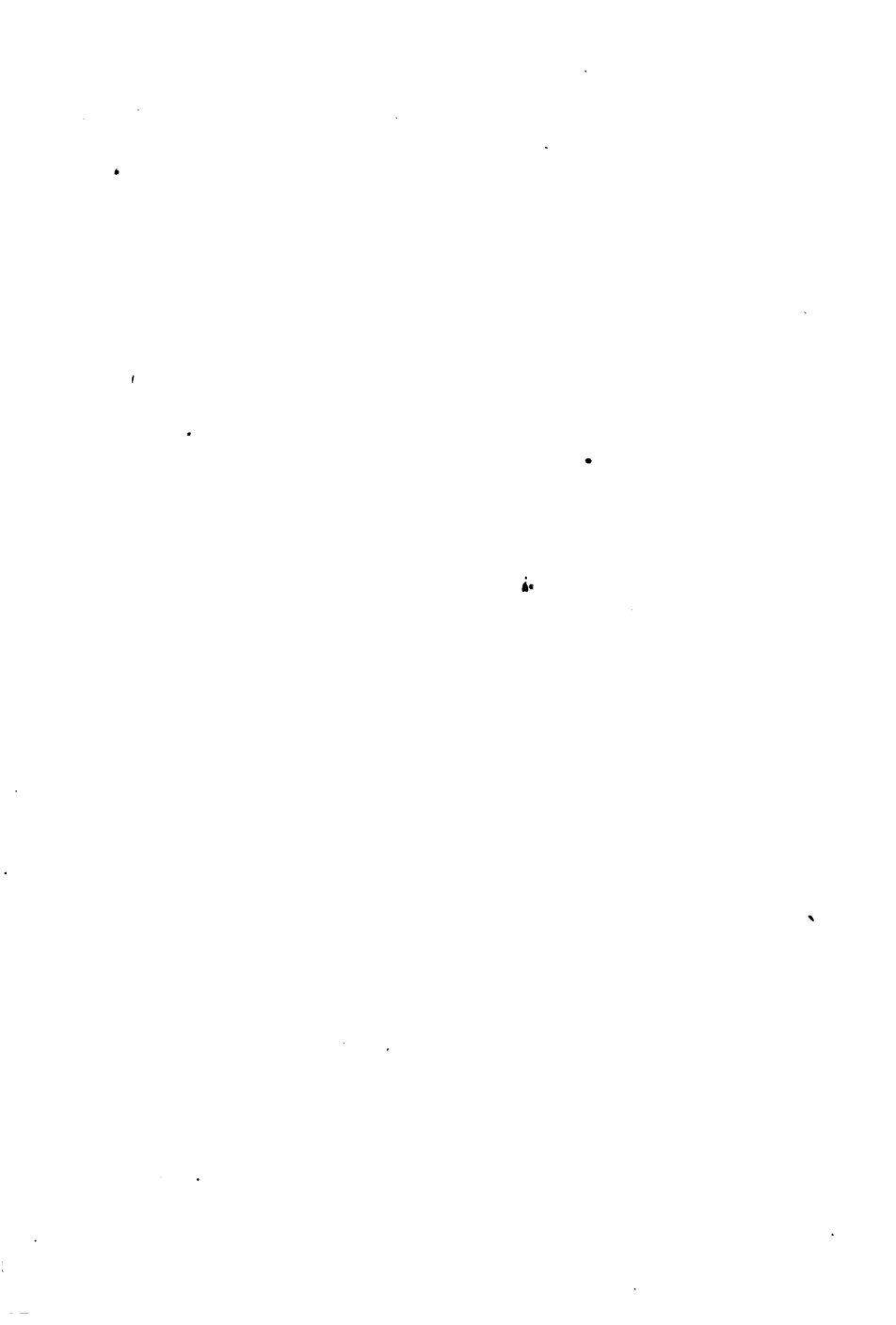
THE FUELS
OF THE HOUSEHOLD

Their Origin

Composition and Uses

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SPRECKELS

TO MY FATHER

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PREFATORY NOTE

IN writing this essay I have assumed an audience of young housekeepers and those who are to become such. I have sought the best information on the subject which the abundant professional and bibliographical resources of the National Capitol afford, but I have thought it best to use a style of direct statement rather than one embracing complex statistical forms.

I am especially indebted to my father, Dr. Charles A. White, whose abundant published writings on geological and botanical subjects are well known. He has not only placed his large accumulation of manuscripts at my disposal, but I have constantly had the benefit of his counsel and of his personal recollections of many of the conditions and events of which I have written.   M. W.

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CHAPTER I

INTRODUCTION

THAT the natural resources of light and heat are universal is shown by the energy and diffusion of the sun's rays throughout the solar system, by the intensity of heat in active volcanoes, and by the fierceness of lightning flashes when storms prevail. So small, however, is the draft that man has hitherto been able to make upon those great natural resources for economic uses that nearly all his supplies for those uses are obtained by artificial means.

To a comparatively small extent the sun's rays have been utilized, and under specially favorable conditions light is now abundantly produced by the artificial control of electric currents, and heat for domestic and other economic uses is largely obtained by the same means. The fact still remains that, with exceptions to be mentioned on following pages, the light and heat which are practically used in the household and industrial arts are artificially produced from substances called fuels, by chemical processes which are ordinarily called combustion and incandescence, respectively.

The same kinds of fuels are used, or are usable, in the household that are used in the industrial arts; and although much the greater part of the fuels which are now utilized by man are consumed in the world's great activities, success in housekeeping is quite as dependent

on the skillful selection and management of fuels as it
is in the case of great industrial enterprises.

The three principal objects for which our household
fuels are used are the warming of our dwellings, the
lighting of them, and the cooking of our food. Although
it is true that light may be produced with little or no
accompanying heat, and that heat may be produced with
little or no light, all the fuels which are now used for
lighting may be, and in many cases are, used for heating.
Therefore the term "fuel" is employed to designate all
those combustible substances which are used in our
households and in the industrial arts to produce either
light or heat, or both. The fuel substances which are
to be considered in the following chapters are such as
are commonly used in the household, and all of them
are obtainable in the fuel markets or from special
dealers.

. For convenience of reference on following pages,
household fuels are divided into solid, semi-solid, liquid,
and gaseous fuels. The solid fuels are mineral coals
and coke, wood and charcoal, and peat. The semi-solid
fuels are wax, fats, resin, stearin, palmitin, spermaceti,
and paraffin. The liquid fuels are the oils and alcohols.
The gaseous fuels are the natural and artificial gases
which are readily combustible, but which are not con-
densible to a liquid condition except at extremely low
temperatures, too low for practical consideration. Fuels
are also in part grouped with reference to their origin;
as some are of animal origin, some of vegetable origin,
and some are derived directly from the earth. The last
mentioned fuels are appropriately called mineral fuels,

although some, if not all of them, are primarily of vegetable origin.

In discussing these fuels and their uses on following pages, the mental scene of all the processes and utilities which are mentioned is the household. The households of our country are so distinctively American that the subject of this essay is naturally devoted to that type. The historical range of that type is short, because the political history in connection with which it was developed is short compared with that of other countries. And yet, eventful as that short political history has been, the household affairs which have pertained to the use of fuels have been quite as eventful.

For example, there are aged persons now living who were born and reared, not upon the westward moving frontier, but among the settled population of the Eastern states, who, during their childhood and early youth, never ate any food that was not cooked either at the open kitchen fire or in the adjacent brick oven. No cast-iron ranges, nor even the commonest cook stoves, had then come into use. Neglected fires were rekindled by means of the flint and steel, or, if the tinder box was out of order, one of the children was sent to a neighbor's house to "borrow fire." A half-burnt brand was taken from the kitchen hearth and swung over the head of the running child to keep it burning. Friction matches were not then invented. The usual household light was that of rude tallow candles, and the best light then available for household use was obtained from whale oil.

This oil deserves special mention because the demand was then so great that ships sailed every sea to obtain

it. Mineral oil, except in quantities too small for practical use, was not then known to exist in our country. When that oil was discovered by deep boring, it came in such quantity, and its refined product, kerosene, came so suddenly and abundantly into use, that the whaling business was destroyed, and the ships returned to port empty and rotted at their docks. Illuminating gas from coal had hardly passed its experimental stage, even in the larger cities, and the most prophetic mind among the people never conceived of lights so brilliant and serviceable as those with which our households and public buildings are now furnished. Churches and public halls were not warmed, and in bitter winter weather the whole family gathered around the roaring wood fire upon the great kitchen hearth. No system of general housewarming was then known, and mineral coal was seldom seen except upon the blacksmith's forge. That such revolutions as these could have occurred with relation to the domestic customs of a progressive people within the memory of an individual is marvelous but true, and the half has not been told.

CHAPTER II

COMPOSITION OF FUELS

BECAUSE the foregoing classification, or manner of grouping, of the fuels is followed in the subsequent chapters, it will be necessary to remember them to have a clear understanding of the statements therein made. It is also quite necessary for one who desires to know fuels to become familiar with the elementary facts pertaining to their composition and their manner of combustion to produce heat and light. It is for the purpose of briefly summarizing those facts that this and the next following chapters are introduced.

The Chemical Elements. Not only the earth and all that pertains to it, including its solid mass as a planet, but its waters and all that they contain, its atmosphere and all that pervades it, and all the animal and vegetable forms which dwell or grow upon it, consist of various kinds of matter which are called elements and compounds of elements. Those chemical elements have never been divided into other substances, as the compounds have been, and they are generally regarded as incapable of such division. Their number at present known is above seventy. In density and other properties they vary from ponderous metals, as iron, on the one hand, to invisible gases, some of which are lighter than air, on the other. Very few elements are found free in nature, but are usually combined with other elements. Every such

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combination produces a substance which is quite unlike any of the elements of which it is composed.

Chemical Reaction. The inclination which the elements have to unite to form compounds whenever they are brought into intimate contact under such conditions as solution and heat varies so greatly that an element will often leave its associate in a compound and unite with another element. The two freed elements either unite to form another compound, or, in passing off, each unites with other elements. This exchange of association is called chemical reaction, and all known substances are liable to be affected by such reaction. Whatever may be the result of such questions as have lately been raised as to the destructibility or transmutability of elements, such possibilities need not be considered with relation to the elements concerned in fuel combustion. We see and handle those elements in their visible and tangible condition, and, although they become invisible and intangible when their combustion has occurred, we demonstrate that they still exist when we account for the products of combustion.

Sometimes chemical reaction is slow, as in the rusting of iron and in what is ordinarily called decay of animal and vegetable substances. Sometimes it is very rapid, as in the burning of fuels, especially the fierce flames of liquid and gaseous fuels. Sometimes it is explosive, as is seen in the so-called fire tests of the mineral oils, and by the disastrous results of the careless handling of gasoline.

The Fuel Elements. There are only a few of the large number of the chemical elements with which we

shall have anything to do in the study of household fuels. Indeed, there are only three of them which take really an active part in the combustion of fuels, namely, carbon, hydrogen, and oxygen; but it will be necessary to mention a few others as accessories to combustion and to ignition, or the kindling of fires. Each of the elements generally assumes a very different condition in every combination which it makes with another element, but such transformations need be mentioned only for those which are immediately concerned in fuel combustion. For example, oxygen, which is so abundant that it is estimated to constitute nearly one-half of the bulk of the earth, exists in a great variety of conditions. It enters largely into the composition of minerals and into the solid part of vegetable matter, where it is necessarily solid. It is a large constituent of water, where it is of course liquid. It constitutes a large part of the atmosphere, where it is closely associated with, but not chemically united to, nitrogen. In that association it is necessarily gaseous, as it always is in its pure state.

The diamond is the purest form of carbon known, and in that condition it is one of the hardest of known substances. Charcoal, coke, and anthracite, although widely different from the diamond, are nearly pure forms of carbon. All the other solid fuels, as well as the semi-solid fuels, are largely composed of carbon, and in these fuels it exists in a more or less solid condition. Carbon also forms a component part of all alcohols and oils, in both of which kinds of fuel it is necessarily liquid. It is an essential component of all the gaseous fuels, and in them it is necessarily gaseous.

Hydrogen in a free state is an inflammable gas, which burns with a bluish flame, and is the lightest substance known. In the gaseous fuels it combines with carbon and still retains its gaseous condition. In combination with oxygen, hydrogen generally assumes the liquid condition, that combination forming water. In all the other liquid fuels of which hydrogen forms a part, it is necessarily liquid. Hydrogen enters into the composition of all the solid and semi-solid fuels, with the exception of pure anthracite, coke, and charcoal. In these fuels it is necessarily in a correspondingly solid condition.

Accessory Fuel Elements. It is desirable to mention a few other elements which enable us to get a more complete view of the nature of combustion. Nitrogen should be specially mentioned in this connection, although it is wholly inert in the process of fuel combustion. It is very abundant everywhere, associated with oxygen in the atmosphere, and when freed from that association by fire it accompanies the products of combustion and goes unchanged to take its former place in the atmosphere. In its pure state nitrogen is a colorless gas, but like other gaseous elements it becomes a solid by some of the combinations which it makes with other elements. Such an example is seen in the well-known saltpeter, or nitrate of potash, which is mentioned among the kindling materials in a following chapter because it is combustible, although not a fuel.

It is proper to mention here that within a few years three other gaseous elements have been discovered in the atmosphere. They are rare, or little known, but in fuel combustion they seem to hold the same position with

relation to the fuel elements that nitrogen does, that is, entire inertness. The names which have been given to these elements are argon, helium, and neon, respectively.

The Importance of Carbon and Hydrogen. In the next chapter statements are made concerning the process of combustion of the different kinds of fuel which show the great importance of oxygen in all those processes; and yet they show that oxygen is not itself a fuel. *The only true fuel elements are hydrogen and carbon;* but there can be no combustion of those elements without oxygen. Being indispensable, it is fortunate that oxygen is always and everywhere at hand, free of expense and requiring no labor for its preparation and storage. On the other hand, hydrogen and carbon must be obtained by great labor and at great expense.

CHAPTER III

COMBUSTION, IGNITION AND INCANDESCENCE

OXIDATION. Oxygen, which is ever present in the atmosphere, has a constant tendency to unite chemically with most of the other elements. Consequently it readily leaves its associate, nitrogen, to unite with them, that being the act of oxidation which is to be so often mentioned in the following remarks. Fuels exposed to the air are all attacked by oxygen and undergo a very slow process of oxidation at ordinary temperatures, and without fire. This open-air oxidation is hardly perceptible, even after long exposure, in the case of the hardest of the solid fuels, but it always exists, and differs from burning by fire only in the length of time in which it is accomplished. Even the amount of heat which is given off in the process is the same in both cases, because, as is well known to chemists, the amount of heat which is given off by oxidation is always in proportion to the extent of that process. In the case of open-air oxidation of fuels, heat is given off too slowly to be perceptible to the senses, but so rapidly in the case of their ignition that combustion results.

Combustion. If fuels are placed in suitable receptacles and fire is applied to them, they also take fire and are more or less quickly consumed. This process is combustion, the well-known burning of fuel, in which, instead

of the exceedingly slow rate of open-air oxidation, there is a violent and rapid oxidation which quickly converts the fuel into what are called the products of combustion.

With the exception of anthracite, coke, and charcoal, all solid fuels contain enough hydrogen to give off more or less flame. When either of those three fuels burn, there is only carbon combustion, and the fire consists of a bed of embers. Hydrogen is often called the greedy element because it will unite with oxygen more readily than any of the others; so when hydrogen is contained in any of the solid fuels it is more readily ignited than is the carbon. After the burning of the hydrogen has ceased, the carbon combustion proceeds alone, forming, as in the other case, a bed of embers which, when exhausted, leave only the ashes. The manner of combustion of the flame fuels will be discussed further on.

Products of Combustion. The products of combustion are, properly speaking, only those invisible gases and vapors which pass off in the upward current that heat causes to rise from the burning fuel. That term does not include smoke, soot, or ashes, but they ought to be briefly referred to in this connection.

Smoke consists largely of finely divided carbon which has been partially oxidized in the fire but not consumed, and, in company with more or less watery vapor, escapes from the fire by the upward draft. Smoke represents wasted fuel; the denser the smoke the more fuel is wasted. The very light-colored smoke which one often sees escaping from chimneys consists largely of watery vapor.

In the burning of wood and some of the softer coals, a part of the oily compounds which are included with

the hydrocarbons are volatilized, escape full oxidation, combine with fine, escaping particles of free carbon, adhere to the inner walls of the chimney flue, and constitute chimney soot. The soot from wood fires is also impregnated with creosote.

Wood ashes consist of certain mineral substances which the growing tree takes from the earth dissolved in its food-sap, together with such accidental impurities as become embodied in, or mingled with, them during the growth of the tree, or afterward. Coal and peat ashes often contain mineral materials which have accumulated while those fuels were forming. Certain of the mineral substances which are contained in the coal ashes are often fused by the fire into lumps which become hard on cooling, and are commonly called clinkers. Excess of ashes, and especially of clinkers, which sometimes occurs in coal ashes, retards combustion by obstructing the under draft. Hard wood ashes contain much potash, which was formerly the chief reliance for making the family soap. Ashes of the pines and of the other conifers contain very little potash, and coal ashes contain no appreciable amount of it.

The chief products of combustion proper are carbon dioxide and carbon monoxide, and, when the fuel contains hydrogen, water is produced as steam. It should be remembered that steam is invisible. What we generally call steam is really watery vapor, or steam in the process of condensation. The two products first named originate in fuel combustion as invisible gaseous compounds that are formed by the chemical union of oxygen from the air and the carbon of the fuel. When two

parts of oxygen unite with one part of carbon, the gas, carbon dioxide, is formed. This gas is heavier than air at ordinary temperatures, but, heated by the fire in which it originates, its relative weight is decreased and it rapidly rises with the upward current, which also mechanically assists it to rise. Carbon dioxide is not only incombustible, but it will extinguish fire as quickly as will water if allowed to cover it. The union of one part of carbon with one part of oxygen produces the gas, carbon monoxide, which is often seen burning with a slight bluish flame over smoldering fires of both coal and wood. It is a product of incomplete combustion, while carbon dioxide is a product of complete combustion, the carbon in the latter case having united with all the oxygen of which it is capable. Both of these gases, particularly the carbon monoxide, are fatally poisonous if freely inhaled.

Water has been proved to exist in the products of combustion of certain fuels which, before their combustion, were known to contain neither oxygen nor water, but to contain hydrogen. This water, therefore, must have been specially formed during the combustion by oxygen from the air uniting with hydrogen of the fuel. Such water passes off in the form of steam, and finally as vapor, together with other vapors, accessories, and products of combustion, as does water which has been incidentally added to the fuel.

Although carbon dioxide and carbon monoxide are the chief products of combustion, there are always accessory gases and volatile products which also pass upward in the current that rises from the fire. These have just been in part referred to, but summarily stated they are,

first, the nitrogen with which its atmospheric associate, oxygen, has parted to take the leading part in combustion; second, water, which the fuel may have acquired before burning; and third, impurities in the air which is supplied to the burning fuel. There may also be some water originating as was described in the next preceding paragraph.

All the solid fuels, hardly excepting the densest mineral coals, so readily absorb water from the earth and atmosphere that some water in the form of vapor accompanies the products of their combustion, as well as the accompanying gases, which are invisible, and therefore give one the feeling that they have been totally destroyed. The fuel, as such, has been destroyed, but each of the elements of which it was composed has only changed from one of its conditions to another.

Without doubt, also, the three rare, lately discovered, gaseous elements which are named in the preceding chapter, argon, helium, and neon, accompany every upward current of fuel combustion. There is something impressive in the subjection of those four quiescent elements to that fiery passage in a process in which they have no part, and whose destination is the same condition as that from which they were taken. They at least emphasize the aggressive action of the oxygen and the greediness of the hydrogen and carbon.

Ignition. Because the slow process of oxidation which all fuels undergo from exposure to the atmosphere differs from combustion only in the slower rate of its progress, it needs only the addition of fire to start the faster rate, which is called combustion. This initial

application of fire to produce fuel combustion is known technically as ignition, but in the household it is known as kindling. No matter how freely fuels will burn under favoring conditions, ignition of all of them must be begun either by fires already produced, or by the production of a small quantity of burning heat that may be communicated by intermediate means to the fuel. There is a large number of materials which have been, or which may be, thus used for the lighting of fires, but the friction match now in use is the most convenient and effective of them all. In the following paragraphs some of the other materials and various methods of employing them are, however, mentioned to show how earnestly man has sought out methods of replenishing his fires. They also show what is more to the point for our present purpose, that fires may be produced by widely different methods.

A very laborious, but a simple and direct primitive method of kindling fires is by rubbing two narrow and perfectly dry pieces of readily combustible wood together, sometimes by holding the pieces at right angles to each other, and sometimes by holding them both in the same direction. Another primitive method of kindling by wood friction is that of rapidly twirling a dry pointed stick in a piece of wood of the same kind, which has been slightly hollowed. In all three of these cases the fine particles of wood which are detached by the friction take fire from the heat which is also produced by it. In these cases ignition of the wood is accomplished without the aid of any other material. All three of these methods are very ancient, and their use lingers only where friction matches are difficult to obtain, or where the production of fire has been part of a religious ceremony.

A method of fire kindling which has long been known, and which even now is practiced by many savage and semi-civilized peoples, is known as that of the fire piston. This instrument consists of a small cylinder of horn, bone, or metal, a few inches in length, less than an inch in diameter, and having a central bore. The bore is closed at the lower end, but open at the upper end, and is usually less than half an inch in diameter. The piston is made of the same, or a similar, kind of material as the cylinder, but longer, and fits the bore closely. A piece of tinder is dropped into the cylinder and rests upon the bottom. The piston is thrust into the bore only so far as to steady it, and then struck a smart blow upon its upper end. The descent of the piston compresses the air in the cylinder so much and so quickly that it is made hot enough to set the tinder on fire.

· Up to one hundred years ago it was not uncommon among our people to keep a "sun glass," which was a common lens of a couple of inches in diameter, for practical use in kindling fires. It was not difficult to start a fire by concentrating the sun's rays with such a lens, but the frequent absence of sufficiently bright sunshine at the time fire was needed made that method of little practical use.

The kindling of fire by means of the flint and steel was perhaps the most widely used of the methods which were practiced before the invention of friction matches. This process is very ancient, and iron pyrite probably preceded steel in producing the sparks by the flint stroke. It is even now retained by some savage peoples in regions where that mineral is frequently found. When the edge

of a flake of flint is struck obliquely upon a small bar of hardened steel, minute bits of the steel are torn off and heated burning hot by the friction of the stroke and the ready action of the oxygen of the air. These brilliant sparks are intensely hot, but they are so small that their heat is quickly lost, and they would therefore be useless if they were not made to fall upon some easily ignited material. Such material is called tinder, and may be of various kinds.

The kind of tinder which was most commonly used in our colonial households and in those of still later date was made by the charring of pieces of cotton or linen cloth, which process changed the cloth to fibrous charcoal. The delicate fibers of this charcoal tinder instantly catch the hot sparks as they fall from the steel, and produce little burrowing patches of sparks of their own among the threads. Rural housekeepers also occasionally used other substances for tinder, among which was a fibrous kind of decayed wood mingled with a fungous growth, and called "spunk" or "punk." Hunters and travelers sometimes used still other kinds of tinder, but the charred cloth was superior to all other kinds, and the tinder box in which it was kept was one of the chief household conveniences.

With great care it is possible to ignite fine wood kindlings directly from the burning tinder, but usually the amount of fire which is produced in tinder is too small for such ignition, and an intermediary substance for the transfer of the fire is necessary. For this purpose the sulphur match was used. It was generally known as the "brimstone match," and was also made in the household.

Sulphur is a distinct chemical element, but, although combustible, it is not a fuel. It melts at a comparatively low temperature, ignites from a spark if only a minute quantity is applied, and burns with a bluish, smoky flame. The match was a slender piece of soft wood, one end of which was narrowed nearly to a point and dipped in melted sulphur. The latter was therefore called the dip, a term which has been continued in use for the corresponding application to friction matches. The small prepared end of the suphur match was applied to the sparks among the tinder, and it quickly became ignited. The sulphur flame at once set the hydrogen of the match aflame, which was then ready to be applied to the candle, lamp, or kindling wood, as we now apply the common friction match.

Early in the nineteenth century a dip was invented which would ignite when the prepared end of the match was thrust into sulphuric acid contained in a small bottle, and quickly withdrawn. That method was not of convenient use, and the invention was soon followed by that of a dip which would ignite by friction.

Friction Matches. Several partial successes in the manufacture of friction matches were made before the practical success of the one which was really the direct lineal descendant of the brimstone match. That is, the first really successful friction matches that came into general use were common sulphur matches, each of which had received a second coating of another kind of dip over its sulphur end, which would ignite by friction on a moderately rough surface. Matches of this simple kind are still in use in some parts of our country.

Many modifications of that primitive frictional dip have been made, with the purpose of abandoning the use of unwholesome or dangerous materials which it contained, besides others since used. Among the substances that have been used in the preparation of the dip are sulphur, phosphorus, mercury, antimony, and the nitrates of potassium and sodium, besides adhesive and other ingredients. The evil effects of some of these substances upon the health of those persons who are employed in the match manufacture are so great that effort has been made to enforce their abandonment.

The invention of the so-called safety match has much diminished the danger attending the general use of friction matches, and has at least partially lessened that which has long attended their manufacture. The dip on these matches consists of a mixture that only with great difficulty can be made to ignite by friction upon any surface except those which have a specially prepared substance spread upon them. Ignition of the dip material of these matches is caused by chemical reaction between the contents of the dip and those of the surface preparation, which must be incited by friction. In the case of the common friction match, friction alone produces enough heat to ignite the dip material; but in the case of the safety match, although friction is necessary, the character of the dip is such that it will not ignite without the aid of an accessory substance. Because matches are so generally used and so constantly within the reach of every one, even of children, it is evident that some such regulation as prevails with reference to kerosene should restrict the use of matches to some safety form. Every

housekeeper should insist on having no other kind in the household.

Without statistical information one is hardly prepared to realize the extent of business operations which are involved in the manufacture of matches in our own and other countries. A reputable magazine recently published the statement of a competent author that seven hundred thousand millions of friction matches are used by the people of the United States every year. One cannot doubt that the proportion used in other countries is quite as great. This little, familiar article alone, which we use and waste so carelessly, makes an enormous draft upon the world's supply of wood which must soon call for national remedy in the planting and protection of forest trees of suitable kinds for its manufacture.

Flame Combustion. Mention has already been made of the combustion of the solid fuels, but because the flame fuels are to be described separately in the following chapters, consideration of flame combustion is brought forward in this chapter that it might follow the discussion of ignition. ✕ The flame of all the lighting fuels consists of hydrogen and carbon, and when they are burned the hydrogen is the first to ignite. Hydrogen, when pure, burns with a faint bluish flame which gives very little light, but in fuel flames hydrogen is always associated with exceedingly fine particles of carbon, which are heated to the glowing point by the burning hydrogen. It is this glowing, or incandescence, of the carbon which gives the yellowish or ruddy light to the flames.

The Candle Flame. Among our immediate ancestors the candle flame was so distinctly associated with

the affairs of their every-day life that its name was used to indicate the time of its lighting. For example, notices of public meetings were habitually given to occur at "candle-light" or "early candle-light," meaning approaching nightfall, or twilight. This flame has the same chemical composition as the flame of the solid fuels, but because of its symmetrical shape and nearly uniform size it has long been regarded not only as the typical household light, but the accepted unit of measurement of the quantity of light which is given off by other flames or other methods. Reduced to exact limits, that unit and its name are still used, even in scientific estimates and specifications.

In the candle flame also is to be observed the manner of combustion of the chemical elements of which the candle is composed. To illustrate these methods suitably, the candle must be made of one of the semi-solid fuels which is hard enough at ordinary temperatures for cleanly and convenient handling, and pure enough to change readily to an oily substance and then to a gaseous condition, without residue, when heat is applied. The candle is composed of carbon, hydrogen, and oxygen, and, as in all similar combinations, this structural oxygen is believed to be inert during combustion. That is, the combustion of the carbon and hydrogen is accomplished by the oxygen of the air only. When the wick of the candle is lighted, the heat of the flame melts a portion of the candle to an oily condition, which then rises by capillary action to the burning portion of the wick, where it is changed to a gaseous state. It is the increased heat which occurs there that causes the change from a liquid

to a gas, and it is the combustion of this gas that gives the flame.

Within the basal part of the flame there is a space which appears dark by contrast with the next outer portion. This dark portion of the flame consists of unconsumed gas, to which that portion of the candle that was changed to a liquid condition is further changed by the higher heat which it there encounters. The luminous envelope, which constitutes the principal part of the flame, surrounds this dark portion. This luminous envelope is the gas in its first stage of combustion, where the hydrogen and part of the carbon are chemically united with oxygen derived from the air. The remainder of the carbon is quickly heated until it glows, which condition is known as incandescence. As the incandescent particles of carbon within the flame pass outward where oxygen from the air has free access, many of them so unite with the oxygen as to form carbon dioxide, which passes off into the air. The part of the flame in which this last named union takes place is the outermost part, and is known as the mantle. It is so slightly luminous as to be almost invisible, but it is the hottest part of the flame.

Some particles of ununited carbon constantly escape from all flames, the effect of which is often seen on the white ceiling above a gas jet. Also, if a porcelain dish is held for only a moment in the luminous part of the flame it becomes blackened. This black deposit is carbon, a part of which had become incandescent, but was suddenly cooled by the porcelain dish and deposited upon its surface. Any interference with the flame is likely to

cause it to smoke. This smoke consists of fine, escaping particles of carbon.

Lamp Flames. The flame of a lamp having the ordinary twisted or braided wick is like the candle flame in structure, shape, and manner of combustion. The fuel in the lamp is already liquid, otherwise the stages in the process of producing the flame are the same as in the case of the candle. The flame of the alcohol lamp, however, gives no smoke, because of the complete combustion of its carbon; but the flame of the oils, especially of the mineral oils, although burned in good lamps, is much inclined to smoke. This objectionable character of those oils is due to the large proportion of carbon which they contain, some of which escapes oxidation. This evil has been remedied to a great extent by flattening and otherwise changing the shape of the wick tubes so as to present a greater surface of the flame to the air, and by providing devices for directing currents of air against the flame. Among the most effective of these devices is the cylindrical wick, which produces a flame of like shape and allows a current of air to pass up along the inside of it as well as the outside. The large cylindrical glass chimneys, through which a strong current of air will pass upward and be directed against the flame on all sides, very much improve the combustion of these highly carbonized fuels.

Gas Flames. The structure of the gas flame is the same as that of the candle and oil flames. It has the same central dark portion, the luminous envelope, and the almost invisible mantle. Unlike those flames, however, the gas in this case is already prepared and ready for

use without any intermediary process. The gas is constantly supplied to the burners by the force which sends it from the gas works. When that pressure is too great, the gas rushes through the burner so rapidly that unconsumed carbon is especially liable to escape, because it has not sufficient time for complete incandescence and oxidation. That excessive flow should be checked at once, because it wastes the gas, diminishes the light, sends unconsumed carbon into the atmosphere of the room, and produces more or less carbon monoxide by incomplete combustion. The small apertures of the burners are placed opposite each other to so spread the flame that it will present two broad surfaces to the air. A large and efficient cylindrical flame is sometimes produced from a burner consisting of a circle of small apertures, surmounted by a glass chimney. But even under favorable conditions gas flames are liable to more or less variation in efficiency.

If the amount of air admitted to the burning gas is much too small, the result is a smoky flame. If the amount is great enough for the full oxidation of the carbon before it has had sufficient time for complete incandescence, the result is diminished light. If a large amount of air is admitted to the fuel in its gaseous condition, before it reaches the flame, the increased amount of oxygen which that air brings oxidizes all the carbon immediately, the incandescent stage being omitted from the flame in this case. The result is intense heat, but no serviceable light. A burner meeting the requirements of complete incandescence of all the carbon of the gas passing through it without complete oxidation has not

yet been produced, but other incandescent lights of remarkable efficiency have been invented.

The Mantle, or Incandescent Light. These devices, which produce a strong and equable light, much superior to that of the most brilliant flame of ordinary gas, accomplish it by the incandescence, not of the carbon of gas, but of a material entirely unconnected with it. It is true that this light is produced by means of a flame of ordinary gas, but the only office of the flame in this case is the production of heat. A blue gas flame is projected upon a small, delicately woven, basket-like structure, called a mantle, causing its instant and complete incandescence, and producing thereby an intense, steady, and pleasant light. In the construction of these fragile mantles several kinds of the earthy minerals have been tried, all of which resist excessive heat, but thorium is the one which is understood to be the most commonly used. It is the mantle only that becomes luminous; the gas itself gives no perceptible light. This mantle light is far more intense than can be obtained from incandescent carbon under any circumstances. The mantle of this light must not be confounded with the mantle of the candle flame. They have no connection with each other except their unfortunate identity of name.

CHAPTER IV

THE SOLID FUELS: MINERAL COALS, COKE, AND PEAT

THE solid fuels generally are used only to produce heat, and not light. One of them, however, bituminous coal, is used in the making of illuminating gas, and large quantities of similar gas are obtained from other mineral coals. Moreover, anthracite is almost indispensable in the production of water gas, as we shall see in a following chapter, but in this chapter we will consider only the character of the solid fuels as heat fuels.

The most concentrated of all the solid fuels are the various kinds of mineral coal. These coals differ in kind from one another, but every kind is important. There is no reason to doubt that the method by which the mineral coals have originated was essentially the same for all of them. It is believed that their differences are largely due to the conditions under which they were mineralized. Doubtless all coals were at one time in a condition similar to, if not identical with, that of peat, so that the method of their origination may be illustrated by the statement immediately following; but peat as a fuel will be described in a still later paragraph.

The Origin of Peat. Peat is in a soft, somewhat plastic condition as it exists in most of the older and deeper deposits, and of a somewhat spongy texture nearer

the top. It varies in color from a light to a dark brown, and is frequently interspersed with roots and vegetable fiber. It consists of the remains of mosses, sedges, and other herbaceous plants which grow in bogs or on marshy ground and at the shallow borders of ponds. As these plants mature in the autumn, they fall down and are covered by the water in or upon the margin of which they grow, and also by the successive annual accumulations of the same kind of materials. The atmosphere is excluded from the fallen plants by the water, and they therefore do not decay as they would if they were to fall upon ordinary ground. Destructive decay of the accumulating vegetable matter is further prevented by antiseptic properties which forming peat possesses. From year to year the accumulations of peat thus proceed, adding to its quantity and increasing the limits and depth of the bog. The plasticity of peat also increases with age, and in wet seasons the bog is liable to burst its bounds and flood the adjacent cultivated land with flowing peat. Well-preserved trunks of large trees have been found buried in peat bogs, that grew in prehistoric times and were probably killed and overthrown in that way. The presence of water in the formation of peat is so necessary that it is never found in arid regions, and the largest bogs now known are in the northern countries of Europe. Deposits of peat are often very small, the more important of them ranging from a few hundred acres to two or three thousand acres. But even the latter are small as compared with beds of coal.

The Origin of Mineral Coal. There is no doubt in the minds of geologists that all the various kinds of

mineral coal are of vegetable origin as regards the fuel substances of which they are composed. Although all the conditions under which mineral coal exists in the earth today are not fully explained by the known origin of peat, that theory of its origin is generally accepted. This view of the origin of the mineral coals implies that during the ages which have passed since the deposits accumulated as peat, disturbances of the earth have caused them to sink beneath bodies of water and to become covered with sedimentary materials which in the course of time changed to rocky strata. This view further implies that the peaty matter, by sharing in the earth's changes which affected the rocky strata, became changed to coal.

There are other facts besides those upon which the theory of its peaty origin is based which justify one in attributing a vegetable origin to all kinds of mineral coal. Coal consists of the same fuel elements that are found in wood and peat, and it differs from all other substances found in the earth by being subject to true fuel combustion. Fossil remains of plants are often found in greater or less abundance in the layers of rock or shale which underlie and overlie the beds of coal, and sometimes they are found in the coal itself. Even in anthracite, the hardest and most compact of all the coals, faint traces of vegetable structure have been found. It is believed that all these plant remains belonged to a great growth of vegetation of which each deposit of coal was formed.

It is only in a part of the geological formations that mineral coal is found, and in some regions of the earth

no trace of it has been discovered. Still, there are only a few countries in which some kinds of mineral coal have not been found. Those districts or regions in which coal is known to exist beneath the surface are usually called coal fields. Some of the coal fields are many square miles in extent, while many are smaller. The coal is found in beds, or layers, which vary from a few inches to several feet in thickness, and in many coal fields separate beds occur, at different depths from the surface. The beds are often of great extent, but the depth at which they lie has no definite relation to the surface of the overlying earth. · As a rule, beds of coal are parallel, or conformable, with the layers of rock, shale, or clay which lie above or beneath them. In some cases the coal and its associated rocky layers have been so disturbed by the earth's movements that they lie at various angles with the horizon, but in other cases they are nearly horizontal. In all cases mineral coal is obtained with great labor, and often with great risk to human life.

The mineral coals differ much in character and quality in different regions and in different mines, even when they bear the same name. Some of them are therefore more suitable than others for household purposes, a fact which should always be borne in mind when coal is bought. Besides the vague terms "hard" and "soft," which are commonly used by dealers for the mineral coals, there are more definite terms generally used in the markets. Still, it is difficult to designate by name all varieties of coal, because different names for the same variety, and the same name for different varieties, are often used by dealers and people of different cities. The

names anthracite, bituminous, semi-bituminous, non-bituminous, cannel, and lignite have long been in common use, and, although not entirely satisfactory, they are chosen for the present purpose.

Anthracite. Of all mineral coals and, in fact, of all fuels, there is no more valuable, or more acceptable, fuel for heating purposes than anthracite. It is the most compact and firm in texture of all the mineral coals, and well deserves its popular name of "hard coal." It can be broken into pieces of any desired size; it breaks with a smooth, bright fracture, and is not inclined to crumble when handled or exposed to the air. When free from mine dust it is the cleanest of all coals, and it has a pleasing, uniform black color. It burns with little or no flame because of the lack of hydrogen in its composition, but when provided with a good draft it burns with a cheerful glow. It consists more nearly of pure carbon than do any of the other coals. It burns with a more intense and steady heat, and for a longer time without replenishing, than do any of the others. Therefore, considered bulk for bulk, it is the most economical of all the fuels. Although there is a considerable proportion of ashes left after burning even the best anthracite, its ashes are generally free from those hard lumps called clinkers, which are common in some other coals.

With such a good record of qualities, one naturally regrets that anthracite forms only a small proportion of the coal supply of the world. Most of that which is produced in America is obtained from a field in Pennsylvania which occupies only a small part of the state. The next most important anthracite fields now known

are in Great Britain, but it is believed that large quantities of this valuable fuel exist in China.

Bituminous Coal. This coal, although of a decided stony hardness, is popularly called "soft coal," probably because it crumbles so easily when handled or when exposed to the weather, or perhaps in contrast with anthracite, which is commonly called hard coal. Bituminous coal contains a considerable proportion of hydrogen, and for that reason it gives off flames freely when its fires are first made, after which its large amount of carbon appears as a glowing bed of embers, which produces great heat.

Bituminous coal is distinguished from other coals in two important respects, namely, from it is produced the highest grade of both illuminating gas and coke. The former comes from its abundant hydrogen, together with some of its carbon, and the latter from its carbon alone. Further mention will be made of both the gas and coke on following pages. Bituminous coal is sometimes called caking coal, because a cake, or crust, is often formed on it when burning. This cake is really coke, and its formation when burning distinguishes the coal producing it from other coals which have a similar appearance. When bituminous coal is burned in an open grate it can be seen to fuse more or less completely into a pitchy, bubbling mass, which is due to the bituminous character of a part of its substance. At the same time it gives off much flame and smoke. It is this portion of the coal that forms the cake which has just been mentioned, and being reduced to comparatively pure carbon by the continued heat, it is consumed with the other carbon of the coal.

More smoke is produced by bituminous coal than by any of the other mineral coals, unless the fires are carefully managed, especially by having a good draft and adding new coal to the fire in small quantities before it has burned too low. This tendency to smoke when burning, and the large accumulation of dirty dust among the broken pieces of bituminous coal, impairs its value as a household fuel. Still, it is in some respects one of the most valuable coals in use.

A large proportion of all the mineral coals, not only in our country, but in the world generally, have much the same aspect as bituminous coal, but they lack the superior quality for gas and coke making which that coal possesses.

Coke. Mention is made of coke in this connection because it is the solid fuel product of bituminous coal. The gaseous product of that coal will be discussed among the gaseous fuels. When bituminous coal is placed in closed retorts, each of which is provided with an escape pipe and highly heated by fires burning underneath, it is not consumed, because no air can enter the retort to furnish the necessary oxygen to unite with the carbon. The heat is continued and the coal becomes a partially melted, bubbling mass, and its volatile parts all pass off as gas by the way of the escape pipes. When the retorts are cooled the residue which is left in them is coke, a valuable fuel, which is almost pure carbon. The use of those retorts for gas making is explained in Chapter VIII, under the head of Coal Gas.

Coke has a grayish, semi-metallic luster, and is light and porous. This porous condition is due to the minute

bubbles of gas which formed when the coal was in a partially melted condition. Coke burns without flame, and as a heat producer the best quality of it is equal to anthracite, in equal weight. The coke which is made for special use in the industrial arts is generally of the best quality obtainable in the markets. The major part of the coke found in the fuel markets comes from the retorts of the gas works, and the quality is not quite so good as that of the other just mentioned. Coke is a very acceptable household fuel for summer use, as it is clean and burns freely. It is usually sold by measure and not by weight. This custom is probably due to its tendency to increase its weight by absorbing water, which has been known to reach twenty-five per cent.

Semi-Bituminous Coal. This variety of mineral coal is similar in appearance to bituminous coal, but it shows little of the character of that coal when burning, as it produces much less flame, and the amount of gas which may be obtained from it is very small. It is more cleanly to handle than bituminous coal, but not so cleanly as anthracite. Its free-burning quality, as compared with the latter coal, makes it a desirable fuel for special household purposes. That which is sold in the markets is found in the region adjacent to the Pennsylvania anthracite field, and it is often sold under the name of the mine which produces it.

In accordance with the generally accepted theory of the origin of mineral coals, it is believed that in some cases after bituminous coal was formed it was changed by some natural process by which it parted with its hydrogen and became anthracite. In accord-

ance with this view it is believed that semi-bituminous coal represents an intermediate condition between bituminous coal and anthracite.

Non-Bituminous Coal. Under this head may be ranged much the larger part of the mineral coals of the world, all of them having the general aspect as well as the black color of bituminous coal. None of them, however, produces good coke as compared with that of bituminous coal, and few of them are good gas coals, even when they are efficient heat fuels. Notwithstanding those deficiencies, the best of them are among the most acceptable of household fuels. The many varieties of non-bituminous coal are not readily distinguishable by name, and it has become customary to give them the local names of the mines or places from which they are obtained.

Cannel Coal. This coal is usually dull black in color, but its blackness is sometimes intense. It is of a more or less uniformly compact texture, without the numerous cross fractures which are so common with other coals, and it is therefore not much inclined to crumble upon exposure. Some varieties are so dense and black that it has been used for the manufacture of articles sold as jet. It burns freely, with much flame, which often assumes the shape of candle flames. This fact gave origin to the name, which is a corruption of candle coal. It ignites so easily that it may often be lighted directly from a match, and because of this convenience and the pleasing effect of the flames it has been much esteemed for use in open fireplaces. Illuminating gas, mineral oil, and paraffin have been obtained from

cannel coal, but its average value is not so great as that of some other mineral coals.

True cannel coal is not found in large quantities in our country, although dealers often sell other blazing coals under that name. Limited deposits, however, have been found in the carboniferous strata of some of the interior states, but the beds which have been found are too thin, and the quality of the coal too poor to pay for mining.

Lignite. Owing to the brown color of true lignite it is often called brown coal. This fuel is found in the earth, as are the mineral coals already described, and its texture resembles that of both mineral coal and peat. In true lignite more or less woody and herbaceous fiber is distinguishable, which shows that trees, as well as herbaceous plants, entered into its original peaty composition, and it is the presence of this woody fiber that gave this coal its name. Although the best lignite burns freely, its fuel value seems to be very little greater than that of the best of peat. Very little true lignite has been found in our country, and it need not be discussed as an American household fuel. It has been found mostly in Europe, but the term lignite has often been applied to some of the poorer non-bituminous American coals, especially to some of those which have been found in the western parts of the United States and Canada.

Peat. Although peat is commercially one of the least valuable of our fuels, it is given general mention with the others because of its assumed relation to the origin of the mineral coals, and of its importance as a fuel in certain regions where other fuels are not avail-

able. Peat deposits, unlike those of mineral coal, have no covering except the accumulation of moss and fallen vegetation which grew there, and which have not had sufficient time to change to peat.

The process of harvesting peat is simple, but laborious and dirty. The surplus water is first drained from the bog and its covering of dead vegetation thrown aside with shovels. Then another kind of shovel, the blade of which is bent longitudinally at right angles, is used to cut the soft peat into angular blocks. These blocks are dried in the open air, just as freshly molded building bricks are dried before they are stacked in the kiln, and the peat is ready for use.

Even when carefully dried and stored, peat thus prepared is liable to crumble by handling, and in that condition it makes a poor, smoldering fire. Many efforts have been made to improve the burning quality of peat, the most promising of which appears to be its condensation into small blocks. All the methods of accomplishing this condensation by pressure seem to have proved unsuccessful as to an increase of fuel value. It has, however, been discovered that if peat is made quite moist and ground to a plastic condition it will dry in masses of considerable hardness, as will brick clay. Peat thus ground and molded into small blocks so shrinks in drying that, when perfectly dry, it has nearly the hardness of mineral coal. Such blocks of peat have been successfully used in both open and closed grates and in stoves. Still, even under the best conditions, peat leaves, after it is burned, a large amount of ashes, mingled with some earth.

CHAPTER V

SOLID FUELS—Continued: WOOD
AND CHARCOAL

ONE who is really in sympathy with nature cannot view the felling of a fine, well-formed tree without almost the feeling that a crime has been committed. Still, we have become so accustomed to those and similar acts that we view the general destruction of vegetable life for our fuel with even more complacency than we do that of animal life for our food. Such sacrifice of other life for the preservation and comfort of our own seems to be a natural necessity, for it cannot be doubted that all our fuels of every kind, including the mineral coals, have been derived from formerly, or now, existing forms of animal and vegetable life, respectively.

Undoubtedly, man's first fires were made with wood, and it is even now in many respects an ideal fuel. It is not used very largely in cities, partly because its cost is comparatively greater than that of other fuels, and partly because it requires greater space for storage. It does, however, largely supplement the use of other fuels, especially in summer, and it is almost indispensable for kindling coal fires. A fair knowledge of the composition and manner of combustion of wood adds much to one's interest in a fuel which is so convenient and the burning of which gives so much comfort.

As in the case of the mineral coals, the combustible

character of wood depends only upon the two fuel elements, carbon and hydrogen; but in some respects there is a great difference between these two general kinds of fuel. For example, anthracite and coke are nearly pure carbon, and they give off no flame in burning; while wood contains a liberal proportion of hydrogen. The latter, together with a portion of the carbon, gives off an abundance of ruddy flames, which are often increased by the presence of resin in the wood. The proportion of carbon is greater than that of hydrogen in all wood fuels, and woods vary greatly from one another with regard to those proportions. The greater the proportion of carbon which a given kind of wood contains, the greater is its heating power, because, although the hydrogen flames temporarily give considerable heat, it is the bed of glowing carbon which remains after the flames have ceased that gives off the desired long and steady heat.

Although wood fuel burns very freely, there are some natural impediments to its complete combustion. Even after it has been seasoned, as the process of drying out of its natural sap is generally called, it so readily absorbs water from the atmosphere and other sources that no wood is entirely free from moisture unless it is kiln-dried. When wood is burned, this water passes off as steam with other products of combustion, and takes with it, in a latent condition, much of the heat which has resulted from the burning of the hydrogen and carbon. Wood, as well as many other fuels, contains much oxygen in its composition, but it is believed that this oxygen is not concerned with its combustion,

and that only the oxygen of the air is so concerned. That is, it is believed that not only does the oxygen which enters into the composition of wood not act as a supporter of combustion, but by uniting with some of. its hydrogen forms water, and so reduces the hydrogen combustion of the fuel. Water formed under such conditions is already in the state of superheated steam, and will, as in the former case, carry off much latent heat. This question of the chemical production of water in the process of combustion of oxygenated fuels seems to be yet an open one, but there is always enough water in the atmosphere to endanger the perfect combustion of wood fuels. In every possible case the free burning of fuels always pays for keeping them perfectly dry.

Although all kinds of woody growth will burn more or less freely, firewood, for obvious reasons, is obtained from mature trees. There are many hundred kinds of trees growing in our country, most of which are native to the respective districts where they grow. The supply for the fuel market, however, is usually obtained from a few of the kinds of native trees which grow in its vicinity. Frugal owners of woodlands generally utilize the "brush," especially for summer use; that is, small branches of the trees and various shrubs which grow among them. Woods are generally roughly classified by dealers as "hard" and "soft," especially if their stock consists, as it often does, only of oaks and hickories, on the one hand, and of pines, on the other. This and other similar groupings of firewood are of some convenience, but they do not give a desired knowledge of trees. It is not practicable to discuss here an extended

catalogue of trees, and therefore only those will be mentioned in the following paragraphs the wood of which is likely to be found in the chief fuel markets of our country.

There is great diversity of names by which the respective kinds of trees are known to the people of the different regions where they grow. For this reason it is often difficult to state a case clearly when writing about wood fuels. The names for various kinds of trees which are used by botanists are intended to be the same everywhere. The same precision ought to prevail in the use of their common names, but unfortunately the common names are not only various but often irrelevant.

A few years ago, however, the United States Department of Agriculture made a strong effort to secure such conformity in the use of the common names of our forest trees as prevails in the use of their botanical names. The Forestry Division of that department has published, in its Bulletin Number 14, a catalogue of the trees of the United States, in which are given both the botanical and common names of the species. The names of the few trees which are specifically referred to in the following remarks are identical with names which are used in the bulletin to which reference has been made.

Before discussing the various kinds of trees which furnish our firewood, it is desirable to state the characteristics of two great groups into which they are naturally divided, because the members of each group have certain fuel characteristics which clearly separate them from each other.

One of these botanical divisions bears the name of Angiosperms, and the other, Gymnosperms, or Conifers. Those botanical names are used here because the divisions which they represent have no common names. The chief differences of structure and foliage between these two great divisions are quite apparent to every one. The angiosperms are well and typically represented by the oaks, with their acorns and broad, falling leaves; and the pines are equally typical of the conifers, with their cones and needlelike, evergreen leaves. As will soon be shown, the wood of each division is distinguished by peculiarities which are quite as striking as are their external characteristics.

The Angiosperms

The wood of the angiosperms, considered as fuel, differs in many respects from that of the conifers. Under the name angiosperms are included all those woods to which dealers give the name of hard wood. They include not only oak, hickory, ash, etc., but many comparatively soft woods, as the soft maples, poplars, linden, willow, etc. The free burning of the wood of the angiosperms is due to their hydrogen, and not to the presence of resin, as is the case to a greater or less extent in all the coniferous woods. A considerable amount of ashes results from the burning of the angiosperms, but it is not excessive. The ashes of the harder kinds contain so much potash that they were formerly almost the only source of supply of that requisite in the domestic manufacture of soap. The wood of the angiosperms contains proportionately more carbon than does

that of the other kinds.. They are therefore more valu-
able as ordinary fuel, and the charcoal which is made
from them is superior to that of all other kinds of wood.

The angiospermous trees are proportionately more
abundant in the eastern part of our country than are the
conifers, while in the western half the reverse is true.
For this reason the Eastern fuel markets are more likely
to be well supplied with hard woods than are the Western
markets.

As a rule, the fuel value of a kind of wood is in
proportion to its density, but other qualities are impor-
tant, and the housekeeper is sure to learn by actual use
of them to form a correct judgment of the value of the
different kinds. For example, in the absence of mineral
coal, when a steady, long-continued heat is desired, the
hardest woods are necessary, but for quick, short fires
in summer the softer woods are more desirable. The
following remarks are not based upon systematic tests
to which different kinds of wood have been subjected,
but are made with reference to well-known general
facts.

In the next following paragraphs mention is made
of the principal fuel trees of our country in an order of
arrangement which is intended as an estimate of their
relative importance.

The hickories, of which there are nine known species
in North America, are doubtless the most valuable of
all our woods for fuel. Of these the shellbark and shag-
bark hickories are superior to all the others, but they
all make excellent firewood. When hickory wood is
dry and sound it burns with a clear, bright flame, and

when this dies down there remains a glowing bed of embers which will last for a considerable time. The supply of this excellent firewood is unfortunately too small in most regions to meet household demands.

The oaks come next in fuel value, and, for several reasons, they are the most important of all. The fuel value of the best varieties of oak is nearly equal to that of hickory, but they vary so greatly that the fuel value of a few of them is not very high. Growing in this country there are nearly fifty kinds of oak, and of these much the greater part produce marketable wood. Oak is therefore more plentiful than any other kind of hard wood fuel. White oak is hardly inferior to the best hickory, especially if the trees from which it is obtained have grown separately and on comparatively poor soil.

There are a few kinds of oak which have comparatively low fuel value, and they are those which generally grow in low or swampy ground. Indeed, it may be accepted as a rule that the trees of any given kind which have the greatest fuel value are those which grow alone and upon upland soil that is too poor for cultivated crops.

The wood of ash trees seldom appears in our fuel markets, because, although there are about a dozen species native to our country, ash trees are nowhere abundant. The wood of all the species is similar in character to that of one another, and its fuel grade is about that of the average oak.

Out of the eight or nine species of maple which are recognized by botanists as growing within the limits of the United States, only two of them furnish a high

grade of fuel as compared with the oaks. These are the
sugar maple and the black maple, which is closely related
to it.

Although birch trees are comparatively abundant in
some parts of our country, they number only about half
a dozen species in all. The best of the birches for fire-
wood is the black birch, or, as it is often called, the
sweet birch. Children and others chew its tender buds
and bark for its flavor, which is similar to that of
wintergreen. The wood of the other birches is of com-
paratively low grade as fuel.

Sometimes there will be found among the wood as
purchased from the dealer sticks of beech, hornbeam,
crab-apple, dogwood, plane tree, and honey locust
mingled with the oak and other high grade cord wood.
The quantity of each of those kinds of wood is always
small and their quality fairly good, so their presence in
the wood pile is not greatly objectionable. Cottonwood,
and all the other poplars, the willow and linden, all
furnish soft wood of low fuel value. The elm, black
walnut, butternut, and black locust, although compara-
tively dense woods, are not of high grade for fuel, as
they do not burn so freely as do most trees of equally
vigorous growth. Although the chestnut is a strong,
sound wood, it is objectionable for open fires because
of the sparks which it throws off when burning.

To make the foregoing suggestions available as to
the relative fuel value of each kind of wood, it is neces-
sary that one should learn to recognize each of the
different kinds by the character of the texture of
the wood itself, apart from that of other portions of the

trees from which it comes. Such knowledge is worth acquiring, and it is not difficult to acquire it.

The Conifers

The conifers, with few exceptions, are evergreens, and their winter foliage presents a strong contrast with the leafless condition of other trees in winter. The woody fiber in all these trees, especially that of pines, is more or less permeated with resin, and the wood is more nearly of uniform grade for fuel, the proportions of resin excepted, than is that of the other kinds. Because of the presence of resin these woods often burn fiercely, and they ignite readily because of their more than average proportion of hydrogen as compared with their carbon. This proportion of hydrogen is so great that the fire is soon burned out. The amount of ashes left after the burning of these woods is very little, and it contains almost no potash. The few hearth coals which are left after the burning of any coniferous wood are soft and crumbly, and the charcoal prepared in kilns from these woods is soft and of low fuel value.

The kinds of coniferous trees are numerous, and they have a great, but variable, geographical distribution. These trees are much more abundant in the Western half of our country than are any of the angiosperms, but in the interior states conifers of all kinds are rare. In the following remarks reference is made especially to those kinds of conifers with which the housekeepers of our country are most likely to meet.

There are nearly or quite forty native species of pine in our country recognized by botanists, and there are

few or no fuel markets in which some of these kinds are not represented. They are all classed as soft woods by dealers, although, on account of the resin which they contain, they vary in both hardness and specific gravity. Sometimes the differences of kind are roughly indicated by the names, pitch pine, yellow pine, white pine, etc., but these names are often inappropriate. The pitch pine regions of North and South Carolina and Georgia are famous for ponderous timber and other products of the pines. Still, a large part of the pine firewood which comes from those regions to various city markets is of poor quality, some of it very poor. This is perhaps because housekeepers continue to purchase such wood.

Occasionally there may be found in the fuel markets the wood of spruce, hemlock, larch, cypress, cedar, and juniper (red cedar) mingled with that of the pines. To this admixture there need be no great objection, because the fuel value of those woods is not materially less than that of the average firewood pine.

The towering sequoias, or "big trees," and the closely related, more abundant redwood trees of the Pacific coast regions are the admiration and wonder of every one, but on this occasion they can be treated only as fuels. The wood of those trees is among the best of the soft wood fuels, being equal to the best pine, except when a heavily resinous wood is desired. It is very cleanly and attractive in appearance, being free from those accumulations of pitch which make the pines so unpleasant to handle.

Unusual Vegetable Fuels. In cases of emergency and irremediable necessity, other vegetable substances

than wood have been used as fuel, such, for example, as the dried dung of grass-eating animals, compressed weeds, grasses, etc. Here may also be mentioned the occasional use that has been made of Indian corn as fuel. When the rich prairie lands of what was formerly known as our Western frontier were first occupied, the settlers raised abundant crops of corn every year, the market price of which was often very low. Trees were scarce, and the distance from markets and developed coal mines was so great that during the stress of winter weather they were often without sufficient fuel. Their corncribs were full, the contents of which were an excellent substitute for fuel; for ears of corn burn as freely and give off quite as much heat as does the best of dry wood. One naturally feels a strong aversion to using an article of food for fuel, but under the circumstances that act was not censurable, and the same settlers who burned corn afterward planted and raised on the same farms large groves of fuel trees. We are apt to forget that olive oil and various other fats which are good human food have been used from time immemorial as lighting fuels. It is not the purpose here, however, to discuss any fuels except those the use of which is now prevalent and consistent with domestic comfort and convenience.

Charcoal. When flame accompanies combustion of carbon in the household use of solid fuels, if not accompanied by smoke, it is not only not objectionable, but often specially agreeable. In household work, however, it is often necessary to have a glowing fire, free from flame and smoke. When it is desired to have a long-

continued fire of this kind, anthracite is the best fuel that can be used for the purpose. Both coke and charcoal, however, are ideal flameless fuels, both of them consisting of almost pure carbon, and both burn freely and steadily.

Charcoal bears the same relation to wood that coke bears to bituminous coal, which has already been discussed. Charcoal is wood which has been freed from its hydrogen and other volatile contents by heat. The crumbling hearth coals which remain after a wood fire are also charcoal, but that which is found in the fuel markets has been produced in kilns specially constructed for that purpose. From the most complete of these kilns we obtain not only the best quality of charcoal, but also many valuable by-products. Among these is wood alcohol, which will be given appropriate mention among the liquid fuels.

The modern kiln, often called the beehive kiln because of its dome or approximately hemispherical shape, is substantially built of brick. An opening is made at the apex through which the wood is introduced, and which also serves temporarily as a draft exit. At the base are openings to admit air to the kindling fire within, and also a larger opening for the removal of the charcoal. Covers are provided for each of these apertures, so that they may be instantly closed when necessary. When the process is completed and the kiln is cooled, all the products are available, but it is only the charcoal and the wood alcohol with which we are now concerned.

Charcoal made in a kiln of this kind from good hard

wood is a most satisfactory fuel for special purposes, and it is ready for immediate use as it comes from the kiln. The wood alcohol, however, must undergo a somewhat elaborate process of separation from the other by-products before it can be used as a household fuel. The fine quality of charcoal made in these kilns breaks with a clean fracture, which is independent of the grain of the wood, and when the pieces are shaken together in the fuel basket they give forth a faint metallic tinkle. Charcoal made of soft wood does not possess these characteristics, and it is dirty to handle and burns out more quickly.

Formerly, rude charcoal kilns were made in the forests by woodmen, and such are now occasionally made to supply local demands. The wood is cut in pieces a foot or two in length and stacked on end in a dome-shaped pile on the ground. The pile is then covered with sod and earth, openings being left at the top and base similar to those in the kilns built of brick, which have just been described. The fire is applied within the openings at the base, and when the mass of wood within is burning well these apertures are gradually closed, but the fire within the kiln does not become completely extinguished until the charring is complete. The hydrogen and all other volatile products pass off through the summit aperture, no effort being made by the woodmen to save them. The charcoal only remains, and is obtained by removing the sods and destroying the kiln. Charcoal made in this rude way is sometimes good, but it does not generally make a very satisfactory household fuel because of the frequent presence in it of uncharred pieces of wood and dirt from the kiln covering.

Tar and Resin. The woodmen of some of the Southern pine forests frequently construct kilns, not for the production of charcoal, but tar, the substance which is proverbially associated with the life of the sailor. Tar is not a fuel, but the method of its production is mentioned here because it is an inversion of the method of charcoal production and a destructive one of wood distillation.

The tar kiln is a hole of inverted conical shape, dug in the earth at the brow of an abruptly sloping bank, so that it may be easily drained out upon the lower ground surface. It is six or eight feet in diameter at the top, but only a foot and a half at the bottom, where an iron pan is fitted which has a drainage spout. The kiln is filled with short pieces of pitchy pine and fired at the top. The fire burns downward, causing the resin to ooze from the wood and mingle with the other products of wood distillation. The mixture is tar, and it gathers in the pan at the bottom of the kiln and passes out by its spout to the receptacle.

Pure resin is produced from pine trees similar to those which produce tar, but it is obtained in quite a different manner. Wounds are made in the trunks of living trees, and from these the viscid pitch exudes, which consists of resin and oil of turpentine. The pitch is distilled in water, that it may not be scorched; the volatile oil of turpentine passes off and is secured. The remainder is commercial resin.

CHAPTER VI

THE SEMI-SOLID FUELS

THE solid fuels are used only as heat producers; even the flame, which accompanies the combustion of some of them, is utilized for heat and not for light. The semi-solid fuels, on the other hand, are adapted to the production of light only. These fuels are completely consumed in combustion, and, if pure, they leave no residue of any kind. Some of them are still used in the household for convenience, but their use has been greatly lessened by the introduction of the mineral oils. Only those which are, or have been, much used in the households of our country are mentioned in the following paragraphs. These fuels vary in consistency from that of lard to that of beeswax and resin. All of them melt at comparatively low heat and return unchanged to their original semi-solid condition on cooling.

The semi-solid fuels which have been selected for mention are fat, wax, stearin, palmitin, spermaceti, and paraffin; and to these resin is added because of its connection with the origin of oil of turpentine, one of the liquid fuels. The five first named semi-solid fuels are sometimes spoken of as oxygenated hydrocarbons, because they consist not only of hydrogen and carbon, but also contain a proportion of oxygen. Although the sixth kind, paraffin, resembles spermaceti, stearin, and palmitin in appearance, it is a pure hydrocarbon, being composed of hydrogen and carbon only.

Fats.   Generally, one is apt to think of fats as animal substances rather than as vegetable products. It is true that many of the fats used in the household are animal fats, but true fats are furnished by the nutlike fruits of many and widely different kinds of plants. Some of not only the animal, but of the vegetable fats consist of two parts, both of which are combustible without residue. As the fat is seen under ordinary observation, these parts are apparently inseparable, but methods for separating them completely have long been in use. One of the parts is an oil and the other is a semi-solid, such as are now under discussion. The proportion of these two parts differs considerably in the fat of different animals; for example, that of the ox differs greatly from that of the hog. The proportion also differs considerably in the fat of individual animals of the same kind, according to the food with which they have been fed.

It is a fact well known to thrifty farmers that the fat of corn-fed hogs is much firmer than is that of those which are either swill-fed or mast-fed. The lard made from the fat of mast-fed hogs is sometimes so soft that it becomes liquid with summer heat of the atmosphere. On the contrary, the kidney fat of the ox and sheep is almost of waxy hardness after it has been freed from its animal tissue by melting, because the oily part of the fat is only slightly represented.

There is now no occasion for the use of any of the fats as household fuels without separating their oily from their semi-solid portions, but formerly lard was occasionally and tallow very extensively so used. A brief description of the manner of using those two fuels for lighting

purposes will be of interest, because it will show how important certain articles formerly were in the household that would not now be tolerated.

Lard Lamps. In the early part of the nineteenth century tallow was constantly used for candles throughout the whole breadth of our country, but upon what was then our Western frontier lard was frequently burned in lamps just as it came from the rendering kettles. This use of lard for lighting fuel was mainly confined to the region referred to, because hog products were abundant and cheap there; but the practice was not prevalent elsewhere, and it did not last many years. This use of lard is mentioned here to show one of the various expedients to which our people resorted to obtain household light. The lamps so used were much like those in which whale oil was burned, but because it was necessary to have the lard in an oily condition before it would rise in the wick it was melted in another vessel and poured into the lamp. Sometimes, to avoid this extra labor, a narrow strip of copper was attached to the side of the wick tube, reaching from the lard to the top of the wick. Sometimes the whole wick tube was made of copper, but as it soon collected verdigris, that use of it was objectionable. Copper is such a good conductor of heat that it soon melted enough of the lard to start an upward flow in the wick when a flame was held a short time to its upper end. In this way the lamp was lighted and gave what was then an acceptable flame.

Tallow Candles. At the time referred to in the last paragraph, the use of the tallow candle was universal,

and the preparation of the candles and of the tallow to make them was one of the important labors of the household. Indeed, the use of such candles was to our ancestors an ancient custom, and they evidently accepted its inconveniences as inevitable.

Among our people, rendered tallow was a common article of merchandise at the village stores, and the butcher sold his candle tallow with his meats, in which case the rendering of it was added to the labor of the housekeeper. The candles which she made were either molded or dipped, the latter process being the more ancient household art.

For dipping candles, a deep iron kettle was placed over a fire, partly filled with water. When the water boiled, enough rendered tallow was put into the kettle to bring its melted surface near the top. The tallow, of course, floated upon the water. The candle wicking, which consisted of loosely twisted cotton threads, was cut into lengths double the length of the candles to be made. These wicks were folded over a slender rod of wood and the two parts slightly twisted together. About half a dozen of these wicks were suspended from each of the rods, each wick being little less than a quarter of an inch in diameter. The wicks, dangling from the rods, were dipped into the melted tallow, the upper ends being held above its surface by the rods, which extended across the kettle. The dipped wicks were immediately hung upon a frame to cool, and were straightened with the fingers. When cooled, the incipient candles were dipped and quickly removed again and again until they were of the desired thickness. These candles were much

like the candles of today, but they were exceedingly crude and unsightly objects.

The molding of candles did not find its way into American households until after the first third of the last century. Previous to that time it had been practiced as a chandler's art, and the candles so made were used in churches and public places. The candle molds which were first introduced for household use were made of sheet tin, and soon became an article of merchandise, together with other tinware. They were cylindrical tubes, usually made in groups of three, four, or six, and slightly larger at one end than the other. There was a conical-shaped cover, with a hole in its apex, through which the wick was passed, which closed the smaller end of each mold. At the larger and open end the wick was held in place by a small, transverse, wooden rod. The melted tallow was poured into the larger end, filling each of the tubes. As tallow shrinks slightly on cooling, the candles were easily withdrawn.

The same large wicks were used for these candles that were used for those that were dipped. Such wicks were only charred, not consumed, as the candle burned down, and the light was thereby much diminished. It was therefore frequently necessary to remove the charred wick with snuffers, which were kept constantly at hand. The small braided wicks which are now used in candles were not then known. These small wicks turn aside to the air as the candle shortens, and the end is there consumed to ashes and needs no snuffing.

Wax. The known varieties of wax are not only numerous but diverse, some of them being of animal

and others of vegetable origin. There are also some mineral substances which are waxlike. Only two of the substances which are called wax need to be mentioned here, as most of those so-called have no place among household fuels. These two are beeswax and the wax which is obtained from the bayberry shrub, or wax myrtle. Indeed, the practical use of both of these substances as accessory light fuels long ago passed away.

Crude beeswax is only melted honeycomb, and was used in that condition to harden tallow candles for summer use. When beeswax is refined and bleached it is of nearly pure white color, and was formerly much used upon religious and other important occasions, but it seldom made its appearance in the household in that refined condition.

Myrtle wax is formed as a slight grayish film on the outside of the small, spherical, seed-like fruits which grow in clusters on the bayberry shrub. This shrub is found growing on open waste grounds of the Atlantic coast region, from Nova Scotia to Florida. The fruit is placed in large kettles nearly filled with water, which is boiled until the wax floats upon the surface. The refuse is removed, and when the water cools the wax forms as a crust upon its surface. Sometimes candles have been formed of this wax alone, but its former domestic use was only to harden tallow candles. Because this wax was never abundant, it was never extensively used.

Impurities, or small bits of any kind which were left in the tallow when it was rendered, or in either of the two kinds of wax when added to the tallow, made the candles "gutter," and thus increased their inefficiency

and ugliness. When no wax was obtainable, alum was sometimes added to the tallow to harden it, but as alum interfered with the burning of the candle and lessened the amount of its light, that method of hardening was seldom used.

Stearin. Chemists know this substance as stearic acid, but the commercial name is stearin, and that name is generally used in the household. Stearin is found in animal fats, and some chemists recognize the corresponding semi-solid of vegetable fats also as stearin, and not always as palmitin. It is separated from its oily associate by a process which leaves the latter in a permanently liquid condition. It was the stearin of the fat of hogs and other domestic animals that first caused the retirement of the tallow candle. The common candle now in use, however, is usually made of paraffin, stiffened with beef stearin.

Palmitin. This substance bears the same relation to the fats of certain kinds of palms and other trees that stearin does to the animal fats. The semi-solid part of that vegetable fat is known as palmitin, but it is so closely like stearin in appearance and use that the housekeeper will generally not care to distinguish them apart. Its associated oil is palm oil, which is much more used in the industrial arts than in the household.

Spermaceti. Few substances of its kind have been longer or more favorably known than spermaceti. It is the semi-solid part of the fat obtained from the whale, mostly the sperm whale, and bears the same relation to their fat that stearin does to other animal fats. The best spermaceti is obtained from the oily fat which is found

in certain parts of the head of the sperm whale. It is among the most beautiful and satisfactory of all the substances which have been used for making candles. When thoroughly purified, its slightly translucent whiteness makes a candle of this substance a pleasing and striking object. It is still occasionally used to make candles for the use of those whose æsthetic tastes prefer its slender flame to the brilliant glare of those illuminants which have driven the candle from common use except as a small portable light.

Paraffin. This name has been used to denote various substances, but by the term as here used is meant the waxy, white, translucent mineral product which is generally recognized by that name in our country. Sometimes it is found more or less pure in the earth, but most of that which is sold in the markets is obtained from petroleum, and is now abundant. In former years it was obtained in comparatively small quantities from certain kinds of mineral coal, and even from peat.

Paraffin is used for various purposes, but its use as a household fuel is only in the form of candles. Such candles burn with a good flame, and the best of them are sometimes sold for wax or spermaceti. Candles made from paraffin alone have a good appearance, but they become so softened by summer heat that they often bend over and lose their shape. It is for this reason that the candles which are sold in the markets consist largely of paraffin stiffened with beef stearin.

Resin. The name resin is applied to many different substances in medicine and the arts. As found in the markets, the substance here referred to is in brown,

brittle, translucent lumps, which break with clean but irregular fractures. Although it melts at comparatively low temperature, it returns to its original condition on cooling. When it exudes from wounds which are made through the bark of pitch pine trees it has about the consistence of honey, but it acquires a brittle hardness after long exposure to the air, or after it has been artificially freed from its oil of turpentine. Its only place among the household fuels of the present day is its occasional application to the ends of kindling wood, that they may ignite more readily. It was formerly used in the making of links, or torches, to light the entrances to large dwellings, especially upon gala occasions. The manner of preparing resin for the market has already been mentioned in connection with that of producing tar from the wood of pine trees.

THE LIQUID FUELS

IT has been shown that the semi-solid fuels produce flame with comparatively little heat, and that they leave no residue of any kind. We are now to see that this is precisely the case with all liquid and gaseous fuels, and that these three kinds form a section which is quite different from the section formed by the solid fuels.

Every liquid fuel is ready at all times to pass up through the lamp wick, or a piece of asbestos in some cases, by capillary action, there to be quickly changed to a gaseous condition and completely burned. All the semi-solid fuels are used in the household only in the form of candles, and the manner of their combustion may be conveniently observed. When the wick is lighted the substance of the candle is melted by its heat to the condition of oil. This newly formed oil passes up through the candle wick just as ordinary oil does in the lamp wick. Thus all the semi-solid fuels are reduced to a liquid, and from a liquid to a gaseous condition before they are burned, and, like the gaseous fuels, they leave no residue after burning. These facts show that the semi-solid fuels are really only congealed liquid fuels so far as the production of flame is concerned, their difference of condition being only one of temperature. Pursuing that idea still farther, we shall see that the liquid fuels and the liquefied semi-solid fuels are only

condensed gases, the difference in each case of practical use being only that of temperature.

The liquid fuels may be divided into two general classes, oils and alcohols. There are several groups of oils and many kinds in each group, but kinds belonging to only two of the groups have been used as household lighting fuels. These are, first, the true oils, sometimes called the organic oils, or fats of either animal or vegetable origin; and second, the mineral oils, which are true hydrocarbons, although the term oil has become inseparably connected with them. Because the true oils contain oxygen besides carbon and hydrogen, they are sometimes called oxygenated hydrocarbons. Some of these oils of both animal and vegetable origin may be used as liquid fuels just as they were obtained from their respective sources, but others of each kind must be separated from a semi-solid substance with which they are associated in their origin before they can be so used. The two oils which are mentioned in the next paragraph illustrate the conditions referred to.

Olive and Palm Oils. These two oils not only serve to show the relation of vegetable oils to one another, but also the relation of a part of them to the semi-solid fuels. These examples also show the similarity of animal and vegetable oils as fuels. Both olive and palm oil are among the oldest known oils used as lighting fuels, but neither of them has ever been practically used for that purpose in American households. In its crude state palm oil is associated with the well-defined semi-solid substance, palmitin, but olive oil is nearly free from such an associate. The flocculence which is seen

in even the purest olive oil in very cold weather is due to the presence of a small quantity of stearin, but that flocculence quickly disappears by the liquefaction of the stearin as the temperature rises. Olive oil has been used from time immemorial, and its religious as well as its secular associations make one almost feel a veneration for it. We have every reason to believe that it was the first oil that was used to light human dwellings.

Whale Oil and Lard Oil. Lard oil is one of those animal oils to which reference has been made as being organically associated with stearin in fats in large and easily obtainable quantity. This oil is now mentioned only to compare it with whale oils, which are almost free from stearin as they are originally obtained. The mention of lard oil again is not for its importance, but for the purpose of referring to the historical fact of its brief domestic use as a household lighting fuel before the discovery of petroleum by deep boring in the earth, which occurred in 1859. That discovery was made when lard oil was used in those parts of our country where hog products were cheap enough to compete with whale oil. That competition, however, was of limited extent and short duration, and it was ended by the introduction of mineral oils to the household, which also ended the use of whale oil in household lamps.

Up to the time of that discovery of petroleum in Pennsylvania, whale oil was the most serviceable lighting fuel then to be obtained in our country, and was more generally used than any other except the tallow candle. The oil of the Greenland whale was the kind then commonly used, but that of the sperm whale was

the best and also the most expensive lamp oil then in use among our people. Those oils were generally used just as they came from the rendering kettles of the sailors, who also carried on a sort of rude chandlery on shipboard for separating the spermaceti from its associated sperm oil.

Before the great discovery of petroleum in Pennsylvania, fishing on the high seas for whales from which to obtain oil was among the great business enterprises of that time. For many years good catches of whales, grampuses, porpoises, and seals were made upon comparatively short voyages by the crews of the smaller vessels, but the great whaling enterprises were prosecuted by means of well-manned ships which sailed from New Bedford and Nantucket as far as Bering Sea, by way of Cape Horn. The average time required for the round voyage of each vessel was about four years. Notwithstanding such length of the cruises, there were so many of the vessels sailing from those two ports alone that their general sailing course was a great marine highway. The large amount of oil which was then taken by those ships found its way into almost every home in our country, until its use was brought suddenly to an end by the flooding of the markets with mineral oil. It is thought well to repeat this reference to that fact because it relates to one of the most sudden revolutions that have occurred in domestic usage.

At the present day our households are so easily and brilliantly lighted that it is difficult to understand how the housekeepers of those early days accomplished any work in a suitable manner during the long evenings, with

their poor and inefficient lights. The lamps which were used for whale and other oils were usually made of japanned tin, and held less than half a pint of oil. The flame of those lamps was clearer than that of the tallow candles, but little if any larger. The lamps were as uncleanly as the candles, if not more so, for oil constantly escaped from the screw-joint of the wick tube and spread as a film over the whole outer surface of the lamp, so that it required frequent wiping. Every housekeeper can see how almost impossible it would be to keep delicate goods from becoming soiled by such lamps.

When we consider the inefficiency and inconvenience of the only household lighting fuels that were available in those early days, we do not wonder that our people were constantly looking for something better. It was of such necessities that our present splendid system of household illumination was born. The trials which our frugal people gave to various products, as already mentioned, showed their habit of inquiry, which is still further indicated in the next paragraph.

Oil of Turpentine. This oil, being very combustible, was thought by a few persons to promise well as an illuminant, and it was so used to some extent before the general introduction of mineral oils. Alcohol was mixed with it and the mixture sold under the name of "camphene," or burning fluid. The lamps in which it was burned were similar in size and shape to those used for whale oil, but each had a slender wick tube, which was provided with a small metal cap to extinguish the flame. This fluid mixture proved to be explosive and therefore exceedingly dangerous in the household. Its use was at

best only an experiment, and it soon went out of use. Its brief mention here is only to show how earnestly the people were groping for better light, and how often they failed.

Oil of turpentine is a true oil of the volatile group, but it is commonly known as spirit of turpentine; and house painters, who use great quantities of it, usually shorten the name to "turpentine." Like all true oils, it contains oxygen in addition to hydrogen and carbon, but unlike those oils it is volatile.

Mineral Oils. The lighter grades of mineral oil are quite as volatile as the oil of turpentine, but they are all true hydrocarbons, being composed of hydrogen and carbon only. The mineral oils have become so important, not only in the household but in the industrial world, that facts relating to their discovery in large quantity, and to the character of the crude oil and its refined products, are of unusual interest. The crude oils are obtained from two sources. One of them, which is called petroleum, is obtained directly from the earth by borings like those of artesian wells; the other, commonly called coal oil, is obtained by distillation of certain kinds of mineral coal or of bituminous earth, or shale. Crude coal oil and petroleum are practically identical in composition and character. Both have a varying brownish color, and both also vary in density according to the proportions of the refined products which may be obtained from them.

Refiners have recognized not less than seven grades of refined oils from petroleum besides the semi-solid products, paraffin and vaseline, all of which are pure

hydrocarbons. All grades of the refined oils mix readily with one another in all proportions and at all temperatures of the atmosphere. The following names have, at various times, been applied to those grades, beginning with the lightest: cymogene, rhigolene, gasoline, naphtha, benzine, kerosene, headlight oil, and lubricating oil. Refiners generally now retain only the following names: lubricating oil, which is the densest grade and is used for lubricating heavy machinery; headlight oil, which is used for headlight lamps of locomotive engines; kerosene, the commonest of household heating and lighting liquid fuels; and gasoline, sometimes used in the household for fuel, but more often used in the industrial arts and for motor engines of various kinds.

All the other names for the successive grades of oil lighter than kerosene have been abandoned by most refiners and dealers, each grade having received the name gasoline with the addition of a number. That is, benzine is gasoline 1; naphtha is gasoline 2; gasoline is gasoline 3; rhigolene is gasoline 4; and cymogene is gasoline 5. All these lighter grades of mineral oils, as well as carefully tested kerosene, are, to the casual observer, simply transparent liquids, having the same general aspect and all readily and permanently mixing together. They also all contain the same two chemical elements, namely, carbon and hydrogen.

Kerosene, as well as the two heavier oils, headlight and lubricating, if properly graded are inexplosive. All the grades of gasoline, however, especially numbers 4 and 5, are so volatile that there is constant danger of their explosion when used in the household for any

purpose. Because several of the names which were formerly used for the lighter grades of mineral oils by refiners and dealers have been discontinued by most dealers, only the names kerosene and gasoline will now be used in this essay for the mineral oils which have a place among household fuels.

Tests of Kerosene. The lighter oils mix so readily and completely with kerosene that it is impossible to detect the mixture by sight. The danger of using such a mixture made it necessary that standards of grade should be fixed by law and municipal regulations, which has accordingly been done in all civilized countries. Formerly there was a constant inducement to violate those laws and regulations, because the lighter oils were the cheaper and it was easy for any person to make the mixture. There has lately arisen a greatly increased demand for the lighter oils and a consequent increase in their price, until it exceeds that of kerosene. Therefore the chief, if not the only, inducement to adulterate kerosene has been removed.

The standard tests which have been established by law are based upon the specific gravity of the oil to be tested, and on what is called its flashing point. Formerly a test was used which was called the burning point, but the flashing test is much the more efficient, and is practically the only one now used. The original way of determining the flashing point was to place some of the oil to be tested in an open cup and to heat it slowly. A thermometer was placed in the oil and the temperature noted at which sufficient gas was given off to cause a slight explosion when a lighted match was applied.

Now, however, there are specially constructed instruments in use, called oil testers, by which the flashing point can more easily and accurately be determined. The flashing test is regarded as absolutely essential by all authoritative regulations, the requirements of which vary from 110° to 200° F. In some of the states municipal regulations require the last named flashing point, which is the highest test required in any country.

To determine the specific gravity of kerosene, an instrument called a hydrometer has been used, and the required rate by that test has varied from .807 to .880. Some municipalities, however, consider this test as of little importance, and therefore do not include it in their regulations. Owing to these state and municipal regulations and the removal of inducement to adulterate kerosene, the use of that fuel is likely to be safe in our households.

The well-known odor which arises from gasoline and impure kerosene is usually due to the vapor of gasoline only, but sometimes a sample of kerosene which has stood the strictest tests of flashing point and specific gravity will have a strong odor somewhat similar to that of gasoline. In such cases the odor is due to the presence in the liquid of a small amount of sulphur, which it has been found very difficult to remove. Its presence, fortunately, is only unpleasant, not dangerous. Such presence of sulphur in petroleum is usually confined to certain regions.

Gasoline. It has already been mentioned that dealers have begun to designate all the mineral oils which are lighter than kerosene by the one name, gaso-

line, and that numbers are now used instead of the former grade names. The gasolines are all explosive, and some of them highly so. Still, even the lightest grades may be safely used by a competent and careful person; but so many terrible accidents have happened in connection with its use that it should not be admitted to the household, even for other than fuel purposes. This judgment of the danger in using gasoline has caused the authorities of New York City to forbid the use of the gasoline stoves in any house, and like regulations are becoming common in other cities. Insurance companies also require that gasoline shall not be used in any house they insure.

The fact that coal oil and petroleum are practically identical naturally suggests that petroleum originated from coal in the earth; but there are many known facts which are opposed to that belief. Although it is true that some petroleum has been found in strata which overlie and underlie beds of coal, yet no petroleum has been found free in any of those coal beds. Also it is certain that the great oil fields of the world have no connection with coal fields. However, it is the general belief of geologists that petroleum has originated from the remains of plants, and perhaps in part from the remains of animals, that formerly existed. Still, it is proper to mention that a noted Russian chemist opposes that view, and claims that petroleum is of chemical origin in the earth.

Alcohols. There are several kinds of alcohol known to chemists, but only two of them are usable as household fuels. These are ethyl alcohol, commonly called

grain, or ninety-five per cent, alcohol, and that which
is obtained from wood, or wood alcohol. They are both
limpid, colorless liquids, which will ignite at the touch
of flame and burn with a strong flame of their own,
which gives much heat but little light, and no smoke
or residue.

Wood alcohol is much less desirable as a household
fuel than ethyl alcohol, and is much less efficient. The
number of calories produced by the burning of wood
alcohol is only about half of that which the burning of
grain alcohol produces. The two alcohols are also very
different in taste, odor, and in the effect upon one who
may drink them. Ethyl alcohol is the alcohol of wines
and other intoxicating drinks. Its odor is not unpleasant
and its taste is slightly biting. On the other hand,
methyl alcohol has an odor and taste so very offensive
that it is undrinkable except by one whose taste has
long been impaired by drunkenness, or otherwise; and
when it is taken into the stomach it is a virulent poison.

Both of the alcohols are composed of the same
chemical elements, carbon, hydrogen, and oxygen, their
differences being due to the different proportions of
those elements in each, and also to the difference in the
manner of their combination. The manner of origin
of these two alcohols is also very different. So far as
is now known, the only method of producing ethyl
alcohol is by the fermentation of some form of sugar,
and its distillation from the substance so fermented.
The reason why this alcohol is so often spoken of as
grain alcohol is that in our country it is largely dis-
tilled from Indian corn, or some other grain the starch

of which has been changed to some form of sugar. Molasses obtained in the process of the making of cane sugar has been much used for the production of ethyl alcohol, and it may be produced by fermenting any substance which contains starch or any kind of sugar.

Methyl alcohol is known by several different names, the best known of which is wood alcohol; but it is often called wood spirit and pyroxylic spirit. This alcohol is not obtained by fermentation, but by a process known as the destructive distillation of wood. Most of the methyl alcohol sold in the markets is obtained as one of the by-products of the wood which is used in the improved kilns for making charcoal, as was described in a preceding chapter.

Although the alcohols are exceedingly volatile and combustible, they do not, properly speaking, explode, as do the lighter mineral oils. They may, however, cause serious damage if spilled on clothing near a fire, because of their ready combustion. Still, they may always be burned safely by careful persons in the well-known small alcohol lamps and chafing dishes and in the modern alcohol stoves. There have recently come into use stoves for the burning of alcohol which are large enough to hold utensils of moderate size. In these stoves the alcohol is vaporized before it reaches the burners, the effect of which is to produce flames similar to those of the blue-flame gas burner.

The extremely high tax which has been for so many years placed on ethyl alcohol by the United States government has had the effect of almost prohibiting its use as a fuel. The increasing demand for fuel, and the

fact that a large number of farm products which have hitherto been thrown away may be made to yield alcohol, has induced the government to reduce greatly the tax on alcohol provided it shall be "denatured." The object of denaturing alcohol, that is, the changing of it from its natural condition, is to render it undrinkable and at the same time not to impair its value as a fuel or its usual use in the industrial arts. What substances shall be added to the alcohol, and in what proportions, is prescribed by law. The substances must be so offensive to the taste that it will make the mixture undrinkable. The chief substance thus prescribed is wood alcohol. In addition there may be oil of turpentine, benzine, carbolic acid, and many other substances. A list of these substances is given on page 8 of Farmer's Bulletin 268, published by the United States Department of Agriculture.

CHAPTER VIII

GASEOUS FUELS

THE term gas is applied to those substances which are invisible and impalpable, and which may be composed of a single chemical element, or a compound of elements, or they may be a mere mechanical mixture of other gases. They are more or less in a condition similar to that of air, which is itself composed of gases. Some of them are incombustible, some support combustion, and some are themselves combustible. It is only the last named class with which we are now concerned.

It is shown in the preceding chapter that all fuels which burn only with flame must be reduced to a gaseous condition before ignition, and that the semi-solid and liquid fuels are in that case really condensed gaseous fuels. The wick in use for both of those kinds of fuel not only localizes the flame, but serves as a vehicle to convey the fuel in its liquid state uniformly and in suitable quantity to the base of the flame. It is here that the service of the wick ends, and here that those condensed fuels become identical with the gaseous fuels. Illuminating gas being already in that reduced condition needs no such preparation, and is burned from small openings in those familiar appliances called burners, through which it is made to pass by pressure within the gas pipes. All the illuminating gases will ignite instantly at the touch of flame or of an electric spark,

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as it issues from the burner, and it is instantly extinguished by shutting off the flow of gas. These familiar facts are repeated here as a basis for references that are to be made in following paragraphs.

It was not until near the close of the eighteenth century that it was demonstrated that gas from coal might be used as a fuel for lighting, and it was many years afterward that its use as a heating fuel was recognized. The first illuminating gas was made from bituminous coal, but other gaseous compounds and mixtures have since been introduced which have largely superceded coal gas in use for both lighting and heating. The artificial gases which are now used as household fuels are known as coal gas, water gas, gasoline gas (sometimes called air gas), and acetylene gas, respectively. Besides these, great quantities of natural gas have been discovered in some parts of our country by boring in the earth. All these gases are spoken of collectively as illuminating gases, although they are largely used for heating purposes also.

Pure coal gas is a pure hydrocarbon, and therefore a perfect fuel. It is the most efficient and unobjectionable of all the gaseous fuels for heating and lighting. It is claimed by some gas experts that a mixture of coal gas and water gas may be made which is superior to any coal gas alone. This assertion has apparently never been proved to the satisfaction of consumers. Coal gas may be made from any coal which contains a large proportion of hydrogen. The best for this purpose is unquestionably bituminous coal, because it is rich in hydrogen and free, or easily freed, from all deleterious

substances. The best of heating coals, anthracite, is excluded in this statement because of its lack of hydrogen.

A part of the process of making coal gas has been incidentally described in Chapter IV as a part of the process of coke making, but it is repeated here to give a connected account of gas making. In the process of making coal gas, the coal is placed in kind of long ovens, called retorts, which have an opening only at the front end, through which the coal is filled. Sometimes these retorts are made of iron and sometimes of a variety of fire-clay, and are set in masonry, with a fireplace under each. A pipe is attached to the upper side of each retort to lead off the gas as it escapes from the coal within. After the coal is introduced, the front opening of each retort is tightly closed and sealed. The retorts are then submitted to a high heat, which liberates the gas and other volatile products from the coal, all of which escape from the retorts by the exit pipes. The gas is immediately passed through a process of purification, while the by-products, which are more or less valuable, are saved. The purified gas is conducted by pipes to a very large receptacle, called a gas holder or gasometer, which has much the appearance of a huge inverted cup.

This huge gasometer, floating, full of gas, upon an open cistern full of water, is connected to pipes which pass under ground to the places where the gas is consumed. It is the weight of the floating gasometer that furnishes the force to distribute the gas in the underground pipes. The gas made and distributed in this way

consists of hydrogen from the coal, together with a part of its carbon. The residue left in the retorts is coke, which has already been described under the head of solid fuels.

Water Gas. This gas is so called because a portion of both the hydrogen and oxygen of which it is composed is obtained by decomposing water. Water, in the condition of superheated steam, is passed over a mass of glowing anthracite and is decomposed by the intense heat of the burning coal. The hydrogen of the water is set free and the oxygen of the water unites with carbon from the anthracite, forming the gas, carbon monoxide. The freed hydrogen and the carbon monoxide together form the mixture known as water gas. This gas mixture, although combustible, produces only a slight flame. Burning hydrogen gives little light but much heat, and the mixture of these two gases alone does not produce a serviceable gas either for heating or lighting. Therefore, to make this mixture serviceable it is necessary to enrich it. The enrichment process was originally accomplished by passing the mixture of hydrogen and carbon monoxide immediately to a receiver, where more of both hydrogen and carbon were added to it. These additional elements were supplied by petroleum, and the mixture of water gas and petroleum was subjected to great heat, which changed the liquid petroleum to a gaseous condition which is so firmly fixed by the process that it cannot return to its liquid condition on cooling. Water gas so enriched is therefore a complex mixture of hydrogen, carbon monoxide, and petroleum vapor.

Recently, a process has been devised by which the petroleum is added to the current of superheated steam before mentioned, so that the enrichment is effected over the glowing anthracite when the water gas is made. Therefore it is not necessary by this new method to pass the gas to a receiver, and it is sent at once to the gas holder for service to consumers.

Even when water gas has been enriched over the glowing anthracite, as has just been described, it is not sufficiently rich in either carbon or hydrogen to make a good gas for either heating or illuminating purposes. It has, however, often been furnished by gas companies to consumers without further improvement. Still, most of the companies which furnish water gas now not only enrich it with petroleum while making it, but they add to it a considerable proportion of good coal gas. This latter addition greatly improves the quality of the gas, which, it is claimed by some experts, is then equal to the best coal gas in both heating and lighting qualities. It should, however, be remembered that even the best of this compound gas contains a large proportion of the poisonous carbon monoxide.

Gasoline Gas. This gas is always made on a smaller scale than that which is furnished by gas companies, and is usually made in private plants for rural dwellings and institutions where large supplies from a gas company are not available. It is a mixture of the vapor of gasoline with air, for which reason it was formerly called air gas. A large tank of gasoline is buried in the ground, the law in such cases generally requiring that it shall not be less than thirty feet from

the buildings, and into this tank of gasoline air is forced by means of a pump, the structure of which is so simple that a child can operate it.

The air thus pumped into the gasoline forces from it the gaseous vapors into which the volatile liquid readily separates, and these vapors and the air together escape through pipes from the upper part of the tank to the mixing chamber. This mixing chamber, or mixer, as it is sometimes called, is nearer the buildings than the tank is allowed to be, and here the gas is mixed with more air, which is forced into the mixer by the same pump that forces air into the tank of gasoline. From the mixer, the gas which has been derived from the gasoline is mixed with so much air that it cannot return to its liquid condition, is conducted by pipes into the building, where it is used for both lighting and heating purposes. As gasoline gas is now prepared it makes an excellent household fuel and does not contain carbon monoxide, which is so large a constituent of water gas.

Acetylene Gas. Besides the gases already mentioned, there is another artificial gas, acetylene, which, like the gasoline gas, is produced only by private plants for country or village homes and separate institutions. Many plants for making this gas have lately been installed. The cost of the plant is not very high, the method of producing the gas is simple, and the gas gives a brilliant light when burning. Calcium carbide, from which acetylene gas is obtained, is now a merchantable article. Pieces of it are dropped automatically into water which is contained in a suitable receptacle. The gas, which is a pure hydrocarbon, immediately

results by chemical decomposition and is ready for use. It is conveyed from the generating apparatus by ordinary gas pipes into the house, and burned as is ordinary gas. This gas, however, requires specially constructed burners.

Many objections have been urged against the use of acetylene gas in the household, notwithstanding the excellence of its light. It is certainly violently explosive, or may become so if not used with great care. It has the reputation of being virulently poisonous if inhaled, but manufacturers of acetylene supplies deny this. The expense of running an acetylene plant is greater than is that for any other gas plant, but the plant itself is not proportionately expensive.

The housekeeper's experience with acetylene gas may be gained under varying conditions. She may be delighted with the brilliant flame which this gas produces as it comes from the pure and clean solution of calcium carbide, or she may have a very different experience, even if the danger of poison and explosion has been overestimated. That is, she is likely to have an unpleasant experience with acetylene gas in its crude state when the flame of the burner of her range "flares back" with a lurid, ill-smelling, and angry flame. That flame is not the flame of common gas that the range is supplied with, but is the result of a vitiated condition of that gas, and consists of a mixture of acetylene and carbon monoxide, both of which are formed at the air inlet of the burner by the incomplete combustion of the gas in use. There can be no question of the poisonous quality of the carbon monoxide, and that of the crude acetylene is not less so.

Natural Gas. This gas, which is a hydrocarbon, occurs naturally in the earth, and is obtained in sufficient quantity for practical use by borings like those which are made for mineral oil and artesian waters. It is a valuable fuel for heating purposes, but it does not give quite so brilliant a light as does coal gas. It is abundant in some regions, but in the greater part of our country it is not known to exist. From some of the well-pipes the gas rushes with great force, but the force of the flow perceptibly diminishes in all of them with their use.

More or less gas of a similar kind escapes from petroleum as it gushes from the wells, and such gas sometimes issues spontaneously in small quantities from fissures in the rocks, or from the earth. It is gas of this kind that causes explosions in coal mines, and is called fire-damp by the miners.

In those regions where natural gas is obtained it is used successfully for both light and heat, not only in the industrial arts, but in the household. As might have been expected, there are sure indications of a gradual failure of the supply of natural gas, and in many places the supply has already given out. This failure has occurred, not only in the less important borings, but in some of those from which the supply was formerly abundant. Geologists generally believe that the origin of natural gas was similar to that of the mineral oils, that is, that it has resulted from some of the great accumulations of vegetable matter that are known to have existed; but the actual proof of such origin has not yet been fully determined.

CHAPTER IX

ECONOMY OF FUELS

THIS chapter is devoted mainly to remarks of a supplementary character upon subjects which have been discussed or referred to on the preceding pages, besides others in which the practical housekeeper is especially interested. None of those subjects is of more importance in the economy of the household, especially in the rural districts, than is that which pertains to the liability to injury of wood fuels, and the necessity of their careful preservation. If these remarks appear to be censorious in some respects, it is because of the prevalent inexcusable wastefulness of wood fuel. That wastefulness is so great as to justify an estimate of a loss of fifty per cent in the possible heating power of the marketed wood fuel of our country. To these remarks are added some statements concerning methods of measurement of fuels, and cautions concerning the use of some of the others.

Although wood is so extensively used as a household fuel, and custom as to the manner of its measurement for sale is nominally uniform throughout the land, no other kind of fuel, and perhaps no other kind of merchandise, is bought and sold with so little regard to its quantity and quality. A legal cord of wood contains 128 cubic feet, and municipal regulations usually require that the sticks shall be of the full length of four feet,

in addition to one-half of the sloping cut at each end. Those regulations also require that the sticks of wood shall be corded with as little space between them as practicable.

By some dealers these regulations are habitually disregarded, and, although many formally comply with the law, full legal measurement is often exceptional. In a not unusual case of this kind a quantity of wood is sawed into very short pieces, put into a cart, and delivered by dumping, with a bill for half a cord. If the purchaser should have a fuel bin four feet long, four feet high, and four feet wide, the exact dimensions of half a cord, and expect that load of wood to fill it if closely packed, it is superfluous to say that he will be disappointed. If the half cord of wood should be purchased as four-foot cord wood, it will not be a hard task to test the measure with a foot rule or a yard stick. It will doubtless appear that the manner of packing of the purchaser will differ greatly from that of the seller.

But the loss to which the purchaser of wood fuel is subjected is far greater with reference to quality than to quantity. Moreover, much of the loss of quality is occasioned, not by intentional deception, but by ignorant neglect and want of that practical sentiment which bestows proper regard upon everything that has borne the impress of life.

There can be no doubt that everything that man has ever used for fuel had its origin in some form of life. The range of fuel origin in extinct forms extends from anthracite, on the one hand, to natural gas, that came from unknown vegetation, on the other. Man has

not only been ready to use the remains of extinct forms of life for fuel, but to destroy that of present forms. It is true that he has innocently obtained large quantities of fats and oils from vegetable fruits and nuts, but when he has wanted animal oils and fats he has sent out thousands of his fellowmen for the slaughter of the whale and seal, and their victims have numbered millions.

After making such havoc with animal life it is not to be expected that he should show any regard for a tree. If he wants firewood, he kills a tree to obtain it. He does not then give it the care which a butcher gives to the body of an animal which he kills, but ruthlessly cuts its graceful trunk in pieces and scatters them upon the ground, where they are left to decay and to the ravages of burrowing grubs. If he is a dweller where trees are plentiful, and desires to cultivate the ground upon which they grow, he girdles them. That is, he kills them by cutting a continuous wound around the trunks with his ax. The trees slowly die, and at his leisure he cuts them up and brings the damaged, worm-eaten wood to the fuel markets. The full extent and character of such damage to firewood can be properly appreciated only by examination of the structure and manner of growth of trees.

The growing tree constantly produces fresh organic substance within its tissues, and it is this substance in the wood that is peculiarly subject to decay. The part of wood which becomes charcoal, or nearly pure carbon, is not subject to organic decay when separated by heat from the organic substances referred to. That fresh organic substance consists of the protoplasmic contents

of the living cells, the delicate walls of which become wood by hardening, thickening, and elongation. The growing cells receive the necessary moisture from the food-sap which the tree absorbs from the earth by its roots. That moisture is constantly present in the growing tree, and remains after it is dead as an aid to decomposition of the delicate cells. The only practicable way to prevent that decay in wood without impairing its fuel value is by thoroughly drying it as soon as possible after the trees are felled, and keeping it dry until it is to be burned.

As one examines the woody structure of the square-cut end of the woodman's log, especially after it has lain a few weeks upon the ground, it is evident that some portions are liable to decay sooner than others. The inner portion of the log, comprising the greater part of its bulk, and commonly called the heartwood, is denser and darker in color than is the narrower portion, having a similar woody texture, which lies immediately outside of it. That outer layer is commonly called sapwood, but botanists call it alburnum. The contrast in color between the heartwood and sapwood is very great in some trees. In the juniper, or, as it is commonly called, red cedar, the heartwood is red and the sapwood is white. In the black walnut the heartwood is brown and the sapwood nearly white. But the difference between the heartwood and sapwood in which we are now specially concerned is shown by the greater liability of the latter to decay.

There is between the sapwood and the bark a very thin layer of cells which is called the cambium layer,

and which is still more subject to decay than is the sap
wood. In the living tree these cells are minute spherical
or polygonal, living, and constantly increasing vegetable
cells. When first formed they are extremely delicate,
but their so-called cell walls soon elongate, thicken, and
take on a woody texture. They therefore become wood
cells on the inner, and bark cells on the outer side of the
cambium layer, their former places in the cambium layer
being constantly filled by new cells as long as the tree
increases in growth. When the tree is cut down it is
killed, and no more cells form in any part of it. Unless
the wood is then very thoroughly dried, the protoplasm
which its cells contain begins at once to decay, and the
decay of the protoplasm soon involves the woody tissue,
especially that of the sapwood and the delicate cells of
the cambium layer. The latter cells are the first to yield.
The outer bark and heartwood resist decay longest
because there is very little protoplasm left in their
thickened and hardened cells.

When the wood of newly felled trees is left exposed
to the weather or stored in a damp place, the effect of
the decay is first noticeable by the loosening and cleav-
ing off of the bark. This is because the new cells
forming the cambium layer have completely decayed,
and nothing remains to hold the bark from falling away
from the wood. This is the first stage of firewood decay,
which is practically identical with the decay of all fresh
vegetable substances. Cut into the sapwood of a stick
from which the bark has been thus loosened and it will
be seen to have a discolored appearance, and a little
later its rotten condition will be unmistakable. This is
the second stage of decay.

Often not only logs and sticks in which decay has plainly begun, but others which are apparently sound may be found to be completely riddled by boring insect grubs which have developed from eggs that were deposited on the outer surface of the bark after the tree was felled. Immediately upon being hatched all wood grubs burrow into the wood in search of remains of the protoplasmic contents of the wood cells, which furnish their necessary food. They have a short, worm-like body and a large head armed with strong, horny jaws. With those jaws the grub tears up the wood to a condition resembling fine sawdust, and swallows every particle of it. The proteid nutriment is absorbed by the intestinal canal from the sawdust-like material as it passes through. The refuse material is continuously evacuated and packed so firmly in the burrow behind the grub, as it goes forward, that the packed material closely resembles the adjacent decaying wood.

The foregoing statements of the effects of protoplasmic decay of wood fuel and of the habits of boring grubs in partially decayed wood have been selected as practical illustrations of the great necessity of carefully drying and housing the wood immediately after the trees are felled. Extreme dryness is the best possible safeguard against most forms of rot and against some of the insect depredations, but unfortunately every case of the latter kind cannot be met so simply.

For example, the hickory borer will attack the wood of that tree only after the tree is killed, and it is so persistent in its attacks then that it will sometimes follow that wood into the woodhouse, refusing all other kinds.

The grub of that insect hatches out in the spring, and therefore if the hickory trees are felled in late autumn or early winter the wood will probably have dried sufficiently to resist the attacks of the grubs when they appear. The mature insect is one of the long-horned (longicorn) beetles, and should be killed at sight. It is desirable to know the habits of other insects in their relation to wood fuel, but only the foregoing statement is selected, because hickory is the best firewood that our country affords, and the hickory borer is one of the most persistent of its kind.

It should not be forgotten that the drying out of the original sap of wood fuel before it is used is absolutely essential, for wood is not suitable for fuel until that original moisture has been removed. The drying out of the sap and all accessory moisture is not only essential in preserving the wood from rot, but in preserving its heating power. Water in the fuel always changes to superheated steam in the fire, and carries off and wastes a large proportion of the heat which the fuel generates.

Measurement of Fuels. All mineral coal is sold by weight, the unit being the ton. Municipal regulation in certain parts of our country requires 2,240 pounds to the ton, but in many parts of it only 2,000 pounds to the ton are required. They are called the long ton and the short ton, respectively. The relation of each of these tons to measured space in fuel bins may be readily learned, and such bins should be well protected, even for mineral coal.

Wood is sold by the cord, of 128 cubic feet. By the

shortening of the length of the sticks and loosely pack-
ing them a difference of fifteen or twenty per cent may
be made in favor of the seller.

Charcoal and coke are sold by the bushel. Although
both of these fuels are hardly subject to decay, they
absorb moisture so readily that they need special care
in housing.

All the semi-solid fuels are sold by the pound. They
are comparatively so exempt from liability to decay that
only ordinary care is needed to preserve them.

The liquid fuels are sold by measure, the unit being
the Winchester, or wine, gallon, containing 231 cubic
inches. As the cans in which dealers serve the mineral
oils to purchasers are rectangular in shape, it is easy
to estimate their capacity.

The gaseous fuels are served to consumers by the
companies measured by a meter, the unit being 1,000
cubic feet. The meter is locked and controlled by the
company, but three small dials on the face of the meter
are visible to every one. These dials are used by the
company in rendering their bills for gas to consumers,
as indicating the amount of gas consumed.

In the purchase of the solid and semi-solid fuels
there is opportunity for the housekeeper to use her
judgment as to quality and quantity of the articles she
purchases. In the case of the liquid fuels, however,
she cannot so easily detect the adulterations and dilutions
which have been practiced. Fortunately, dilutions of
kerosene are not now to be feared, but those of the
alcohols may occur in any degree that a dishonest dealer
may venture to practice. In the case of gas from the

public plant, she must, as a rule, abide by the custom of the company as to the quality, quantity, and pressure of service.

Injurious Fuels. The fact that serious injury to persons and property may occur from contact with fire is too well known to need mention except in connection with cases of special liability to injury from the use of certain fuels. There are three different sources of danger besides that of common fire to which the household is exposed in the use of its fuel, namely, that of suffocation, poison by inhalation, and explosion.

All the kinds of gas which are used for lighting or heating are liable to explode, often with great violence, upon escaping from the pipes and mingling with the air. All kinds of those gases will produce suffocation to the person breathing them in considerable quantity, and at least a part of them will also act as a virulent and sometimes fatal poison when taken into the lungs. Fortunately, poisoning by ordinary contact with any household fuel is not to be feared, and with the exception of wood alcohol no fuel substance has the reputation of being poisonous in the stomach. One will readily see that both the wood and ethyl alcohol ought to be kept beyond the reach of those who may possibly misuse them.

Safety to the household requires constant watchfulness against gas leakage of all kinds, especially as regards its explosive qualities. Leakage is best detected by the odor of the gas, which is usually strong and unmistakable. Upon perceiving the odor, the room or suspected place must at once be fully ventilated by opening the doors and windows. On no account must a lighted

match or other fire be admitted until the ventilation is complete. The leak may then be sought by the sense of smell, and if the odor is strong the escape must be stopped at once by turning the stopcock of the house supply pipe, which is to be found at one side of the meter. If the odor is slight, the leak may be sought by holding a lighted match to the suspected place of issue. If the leak should be there, a jet of flame will issue of a size comparable with the aperture. No leak, however small, must be neglected. Danger always lurks with escaping gas, and safety lies in complete repair.

The flare-back flame which so often results from the lighting by a match of the blue-flame gas burners, whether used for lighting, heating, or cooking, should be immediately stopped by turning off the gas and re-lighting it as often as is necessary to obtain a pure flame. Because this flame consists of a mixture of carbon monoxide and crude acetylene gas, the necessity of cutting off its flow is quite apparent.

The Fireless Cooker. An effective method of cooking certain kinds of food is by simmering for a long time over a fire so small as to keep the food at a temperature just below the boiling point of water. A method of similar cooking may be conveniently accomplished by a device which is popularly known as "the fireless cooker," which is mentioned here because of its present increasing popularity and usefulness. It also serves as an illustration of the fact that a very large proportion of the heat which is produced in all of our ordinary methods of cooking is utterly wasted. The present rate of diminution of the world's supply of fuel makes this subject one of increasing importance.

This device is cylindrical or rectangular in shape, and may differ much in details of construction. The most effective kind consists of a double box of either wood or metal, the larger part including the smaller, so that there shall be a considerable space between them, to be filled with asbestos fiber or some other non-conductor of heat. Still, the box is often made without the interspace, but of material which is known to resist the escape of heat. Usually the top or one side of the box is removable or hinged as a door, and the joint between it and the box is secured by some non-conducting material. Whatever may be the modifications of structure, it is imperative that provision shall be made for the retention of heat within the box.

The smaller cookers hold only one or two vessels of food, but the larger kind may be as large as a small traveling trunk and may hold several food vessels, packed upon one another if necessary, for which reason the covers should be flat. To increase the heat within the box, heated plates of cast iron may be used to over-lay the covers. The food, each kind in a separate vessel, is heated to boiling over a common fire, where the cast iron plates are also heated, and all are placed in the box, previously warmed before the fire. The closed box is then put in a protected place for several hours, when the food will have become thoroughly cooked and remain still hot.

The cooking of the food by this method is effected wholly by the preliminary heating that is given it over the fire, that heat being retained in action upon the food, and its escape prevented, by the non-conducting material.

While these cookers are a valuable addition to domestic needs, it is true that they are adapted to only a part of the requirements of the household for food variety. Still, an ingenious housekeeper may readily adapt one of these cookers to the preparation of a good variety and generous quantities of nourishing and acceptable food, with an important reduction of her own labor and of expense for fuel.

CHAPTER X

ELECTRICITY

ALTHOUGH the object of this essay is only to discuss fuel substances, so much advance has been made in the substitution of electricity for household fuels that brief mention of it is here appropriate. All recent text-books of physics describe what is now known of the character and action of electricity, and the literature of that subject is abundant. It is sufficient, therefore, to say here that electricity is not a substance, but a force, or a form of energy, that under certain conditions flows as a permeating, instantaneous current in certain directions through various substances, but not through others. The former are called conductors and the latter non-conductors of electricity. The current flows with much greater force through some conductors, copper and iron, for example, than through others. Glass and India rubber are among the most complete non-conductors. Many substances, among which are carbon and various metals, are tardy conductors of electricity, and when inserted by attachment between the severed ends of a good conducting wire they resist the current. It is this resistance that causes the heat or incandescence, or both, in the resisting material. This heat is sufficiently intense for all household purposes, and the incandescence gives a light of great and agreeable brilliancy.

Materials of different degrees of conductivity and resistance are used in the construction of electric lighting, heating, and cooking appliances, a large variety of which are now offered for sale as ordinary merchandise in all of our principal cities. The electric light bulb, with its long folded carbon filament, has become a familiar object, but the use of the heating and cooking appliances does not expose them so much to public observation. The heating devices take various forms of radiators, and those which are constructed for cooking are similar in general form and practical use to those in which the gaseous fuels are burned, but of course the details of their construction are very different.

The advantages of the household use of electricity are its capacity for producing abundant light and heat and its entire cleanliness and freedom from objectionable odors. There is no escape of gases or of products of combustion into the air of the room in which it is used, as is always the case to a greater or less extent when liquid or gaseous fuels are burned. The disadvantages of its domestic use are its present greater cost than that of fuels, and the necessity of establishing a comparatively large plant to insure a sufficiently large and constant supply of light and heat. Electricity is therefore not at present practically available as a full substitute for fuels except in cities and the larger villages, or near waterfalls or other natural sources of mechanical power. Recourse to such sources of power is necessary because all the electricity which has been brought under human control is produced by its artificial transformation from other forms of energy. Indeed,

most of the electricity which is now in use is generated by power which has been produced by the burning of fuels.

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FOURTEEN DAY USE
RETURN TO DESK FROM WHICH BORROWED

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